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EXPERIMENTAL RESEARCHES

PHILOSOPHY

PERMANENT COLOURS

DYEING, CALICO PRINTING

VOL. I.

PHILADELPHIA

A. Seybert

EXPERIMENTAL RESEARCHES

CONCERNING THE

PHILOSOPHY

OF

PERMANENT COLOURS;

AND THE

BEST MEANS OF PRODUCING THEM,

BY

DYEING, CALICO PRINTING, &c.

BY EDWARD BANCROFT, M.D.

FELLOW OF THE ROYAL SOCIETY OF LONDON, AND OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES, OF THE STATE OF MASSACHUSETTS BAY.

"Cet art (de la teinture) est un des plus utiles et des plus merveilleux qu'on connoisse; et si *quelque un peut inspirer un noble orgueil à l'homme, c'est celui là:* non seulment il a procuré le moyen de suivre et d'imiter la nature dans la richesse et l'eclat des couleurs; mais il paroit l'avoir surpassé en donnant plus d'éclat, plus de fixité et plus de solidité aux couleurs fugaces et passageres dont elle a revetu tous les corps qui composent ce globe."

CHAPTAL, *Elémens de Chimie,* tom. iii. p. 185.

VOL. I.

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PHILADELPHIA:
PUBLISHED BY THOMAS DOBSON, AT THE STONE HOUSE,
No. 41, SOUTH SECOND STREET.
William Fry, Printer.
1814.

CONTENTS OF VOL. I.

PREFACE.

THE arts of dyeing and calico-printing, having attracted my particular attention so early as the year 1769, I published a volume in 1794, under the title of Experimental Researches concerning the Philosophy of Permanent Colours, &c., intending that it should have been followed by a second, as soon as my other avocations would allow me to prepare it for the press. But my progress in that work was unexpectedly retarded, until the year 1799, when a bill, which *had passed* the House of Commons for granting me a more adequate remuneration for some of my former discoveries, having been *lost* in the House of Lords, (from causes mentioned in the second volume of this work, Part II. Chap. 2,) it became my duty to withdraw my attention from the intended publication, (at least for some time,) and employ it upon matters which seemed more likely to compensate the severe disappointment I had thus suffered. For this purpose I made two voyages, one to North, and the other to South America, in both of which my expectations were frustrated by ill health: and having then attained an age but little suited to a renewal of such undertakings, I resumed, and have for several years continued those pursuits which have terminated in this work; and I did it with the greater alacrity, upon finding, after the whole edition (of one thousand copies) of my former publication had been exhausted, that second-hand copies, when they could

be procured, were currently sold, (though without any benefit to me,) for *six times* their original price.

It may be readily conceived, that the numerous chemical discoveries produced during nineteen years, which have nearly elapsed since the publication of my former volume, must have given occasion for many additions and corrections; especially as, during this interval, I have made several thousands of experiments relating to the subjects of it. For a considerable time, I hoped and expected that these additions and corrections might have been printed separately, to suit and improve that volume; but they have ultimately been found so numerous, and interspersed through so many of its pages, that nothing but confusion and useless expense could have resulted from such an endeavour to accommodate the possessors of it, and enable them to *assort* and *connect it* with the second volume of my present work; especially as an alteration in the arrangement of some parts of it had become expedient. Their condition, however, will only be such as is commonly produced, by the publication of a new and improved edition of any book.

In arranging the subjects of this work, it would have appeared most natural, to treat *separately* of *each* colour, and of the means of producing it; but as the same colouring matter, by changing the basis or chemical agents employed with it, will often produce very different colours, this course of proceeding must have occasioned many repetitions, and a frequent recurrence to the *same* colouring matter. I have, therefore, made another arrangement, which will, I think, enable me to communicate my ideas intelligibly, with the fewest repetitions, and without separating matters essentially connected to each other: and in doing this, I have endea-

voured to avoid minute descriptions of such manual and mechanical operations in dyeing and calico-printing, as are in common use, and not connected with the *principles* of the art, because the artists know these operations already, and to mere speculative or philosophical readers, a knowledge of them would be useless.

I have, in the course of this work, commonly adopted the language, and, with a few exceptions, the principles or explanations of modern chemistry, not as being wholly unobjectionable, but as ACCORDING best with known facts, and being most likely to become parts of a more perfect system, when future discoveries shall have laid a sufficient foundation for the construction of one. I have not, however, been convinced of the expediency of adopting some of the opinions recently promulgated by Sir Humphrey Davy; though I hope and believe, that I am properly disposed to admire his extraordinary talents, and acknowledge the important additions made by him to chemical science. This is not the place to discuss, and, therefore, it would be improper to dispute any of his facts; but I hope it may not be deemed improper for me to mention a few of the objections to which some of his conclusions seem liable.

He supposes himself to have proved that the fixed alkalies (and several of the earths) are *metals* combined with oxygene, or, in other words, metallic oxides; and that when the oxygene has been separated by the powerful agency of opposite electricities, from the bases of these alkalies, the latter are reduced, each to its proper metallic state, and though the supposed *metallic globules* so produced, cannot be retained in this state for a single minute without burning, and again becoming potash and soda, and are besides much lighter than water, he has thought it right to consider and arrange them as *metals*,

under the names of potassium and sodium.* He, (Sir H. Davy,) admits that "a considerable degree of specific gravity was formerly considered as an *essential* character of metallic substances, but (he adds) I have discovered bodies lighter even than water, which agree in all *other* essential qualities with metals, and which *consequently must* be arranged with them." See "Elements of Chemical Philosophy," p. 319. How it should follow that bodies which agree with metals in all but *one essential* character, "*must*" be arranged with them, I am unable to conceive: for to my understanding, an *opposite* inference seems the most natural, and, indeed, the only allowable one. But is it true that the bodies in question do really possess *all* the other characters which are deemed essential to the constitution of a metal? Is not the strong propensity of potassium and sodium to burn instantaneously in the air, and as instantaneously to decompose water, without acquiring, in either case, the properties of metallic oxides, at *variance* with all former ideas of the nature and essential characters of a metal? Even the *shining* quality of these supposed metals, which more than any thing else seems to give them a metallic appearance, belongs equally to petroleum, when diffused upon the surface of water, and to indigo when dissolved for topical application by calico-printers, as is hereafter described. Sir H. Davy has admitted (p. 321 of his Elements) that "the common metals, in consequence of their fusibility, malleability, hardness, and durability, have been the most important instruments of the arts;" and that "the uses of them have been essential to the progress of civilization:" and, after such an admission,

* Gay Lusac, and Thenard, have supposed these productions to be compounds of potash and soda with hydrogene, (or hydrures) and Curadau has thought them to be compounds of charcoal, or charcoal and hydrogene, with potash and soda.

it may, I think, be reasonably asked, why they are to be confounded with matters which have none of *these characters?*

Surely, if it be expedient (which I do not perceive) to comprehend things so dissimilar, *under one common or general denomination*, it would be much more convenient to *invent* a *new* name for that purpose, and allow us to designate matters of such high importance as the metals, properly so called, by that which has been so long appropriated to them. To confound, by *one* appellation, substances so unlike each other, as those commonly called metals, earths, and salts, must be highly inconvenient for the ordinary purposes of life, as well as for the operations of human intellect; and it must be no small addition to the evils of this confounding, to have it extended even to water, and to that fluid of which our atmosphere chiefly consists, nitrogene; both of which, as a consequence of these doctrines, are to be deemed *metallic* oxides (i. e. of hydrogene.) It cannot, I think, be necessary for the advancement of science, that we should thus perplex our language and ideas, and subvert those distinctions which have long regulated the actions and opinions of mankind; and I have, therefore, abstained from these innovations in the following pages. There is, indeed, an additional reason for not considering in this work the alkalies as metallic oxides; which is, that *their effects in dyeing* are as *opposite as possible* to those of the oxides of metals, properly so called: and in regard to alumina, (or the earth of alum) which is supposed to contain a peculiar metal, called by Sir H. Davy *aluminum*, I must declare that the evidence or probability of its existence, appears to me much more feeble even than that which regards the supposed metals of the alkaline earths; which last, in my judgment, is far from being

sufficient to warrant his arrangement of them in the class, and under the denomination, of metals.

It will be seen, also, that in the following pages I have not adopted the name of *chlorine*, by which Sir H. Davy would distinguish that substance, which *Scheele* supposed to be muriatic acid, freed from hydrogene; and which Berthollet afterwards, with the general concurrence of modern chemists, declared to be muriatic acid, combined with oxygene; whence it was denominated oxygenated muriatic acid, and by abbreviation, oxymuriatic acid. Whether Sir H. Davy be correct in adopting Scheele's view of the nature of the oxymuriatic, and the muriatic acids, and in concluding, as he has done from his own experiments, that the former (chlorine) is a simple or elementary substance, and that the latter "consists of hydrogene and chlorine in equal volumes;" or whether the French chemists, (in conceding to Davy, that no experiment has yet incontestably proved that oxymuriatic acid gas contains oxygene) are, notwithstanding, justified in concluding, that the theory which admits or supposes this to be the case, is more natural, and accords better with the whole *system* of chemical facts, than the opposite theory, is a question which seems to be yet attended with doubt and difficulty; and so long as any doubt remains on this subject, I think it best to abstain from such changes of names, of which there have already been but too many; and even if a new name were expedient for the oyxmuriatic acid, I should think that of chlorine, as a *radical*, to have been ill chosen, because its indication of a *green* colour must be useless, by being applicable to so many other things, and because it is not suited, by different terminations, to signify those various combinations, of which this acid is a simple substance, must be susceptible; a defect, which seems to have induced the inventor to adopt

the monosyllable *ane*, as a termination applicable to its compounds with different metals, and thus to create the terms of argent*ane* for horned silver, stann*ane* for the liquor of Libavius, antimon*ane* for butter of antimony, &c.; appellations which do not afford the smallest indication of the radical in question, and which are completely at variance with that nomenclature which Sir H. Davy has employed for the other chemical agents. To me it seems, that if a new denomination were required for the oxymuriatic acid gas, that of *murigene*, suggested by M. Prieur, would be greatly preferable to chlorine; especially as it would *harmonize* completely with oxygene, hydrogene, nitrogene, and other parts of the chemical nomenclature; and by varying its terminations, it would indicate all the compounds formed with it; e. g. instead of argentane and stannane, it would produce muride of silver and muride of tin; and there would be no incongruity between this last and the muriate of tin, to which it would be convertible by an addition of water.

The volumes herewith offered to the public, are founded, as will be seen, upon the results of a multitude of experiments, made during the course of almost half a century; with no inconsiderable expenditure of money, and a much greater one of time and of mental exertion; for which I can never expect any adequate remuneration or benefit; and, therefore, I must hope that these my labours may eminently contribute to advance, not only the practice but theory of the arts to which they relate, as well as other branches of science. I have written, indeed, with more extended views than those which relate merely to practical dyers, &c. and have, therefore, often introduced matters, not of high importance to the latter, though they could not have been properly omitted in a work which professes to

teach the philosophy of colours. Should it ever have been matter of reproach that no *original Work* on this subject had appeared in the English language, the foundation of that reproach will be removed by this publication, which I have endeavoured to render capable of affording both entertainment and instruction to persons who probably would not have been induced to read a more practical treatise on dyeing, &c.; and that the many important subjects contained in it may be rendered as *available* as possible, I have added a very copious general Index to the second volume.

EXPLANATION OF TERMS.

As many of those, for whose benefit this work is intended, may not have been conversant with the new Chemical Nomenclature, I have thought it proper to insert the following explanations of some of the terms which will occur in the following pages: viz.

Acetates	Salts formed by the pure acetic acid with different bases.
Acetate of Copper	Copper in combination with acetic acid.
Acetate of Iron	Iron in union with acetic acid.
Acetic Acid	Strong dephlegmated acid of vinegar.
Acetous Acid	Undephlegmated acid of vinegar.
Adjective Colours, or Colouring Matters	Those which acquire their lustre and permanency by being adjected or applied upon a suitable basis.
Alumina, or Alumine	The pure argillaceous earth of alum.
Ammonia	Caustic volatile alkali.
Ammoniates	Combinations of ammonia with different bases.
Arseniates	Salts formed by the acid of arsenic with different bases.
Azote or Azotic Gas	The phlogisticated air of Priestley and others, the basis of nitric acid, and therefore called nitrogene.
Caloric	The matter or cause of heat.
Carbonates	Combinations of carbonic acid with different bases.
Carbonate of Lime	Lime united to carbonic acid—Chalk.
Carbonate of Potash	Fixed vegetable alkali united to carbonic acid.
Carbonate of Soda	Mineral alkali united to carbonic acid.
Carbone, or Carbon	Pure charcoal, or its basis.

Carbonic Acid	Oxygene united to carbone, commonly called fixed air.
Citrates	Salts formed by citric acid with different bases.
Citric Acid	The pure acid of lemons.
Fluates	Salts formed by fluoric acid with different bases.
Fluoric Acid	That which is obtained from fluor spar.
Hydrogene Gas	Inflammable air.
Muriates	Salts formed by muriatic acid with different bases.
Muriatic Acid	The acid of sea-salt, or common salt—Marine acid.
Muriate of Ammonia	Muriatic acid united to ammonia.
Muriate of Silver	Muriatic acid combined with silver.
Muriate of Soda	Muriatic acid united to soda—common or sea-salt.
Muriate of Tin	Muriatic acid combined with tin.
Murio-Nitrates	Salts formed by muriatic and nitric acids with different bases, the muriatic being in the greater proportion.
Murio-Sulphates	Salts formed by muriatic and sulphuric acids with different bases, the muriatic being in the greater proportion.
Murio-Sulphate of Tin	Tin dissolved by muriatic and sulphuric acids.
Murio-Tartrites	Salts formed by muriatic and tartaric acids with the different bases, the muriatic being in the greater proportion.
Murio-Tartrite of Tin	Tin dissolved by muriatic and tartaric acids.
Nitrates	Salts formed by nitric acid with different bases.
Nitrate of Alumine	Alumine combined with nitric acid.
Nitrate of Copper	Copper united to nitric acid.
Nitrate of Iron	Iron in union with nitric acid.
Nitrate of Lead	Lead combined with nitric acid.
Nitrate of Potash	Nitre, or saltpetre.
Nitrate of Silver	Silver in union with nitric acid.

Nitric Acid	Colourless acid of nitre, or aquafortis, in which the basis is saturated with oxygene.
Nitrogene	The basis of the nitric acid.
Nitrous Acid	Red or smoking spirit of nitre, in which the nitrogene is in excess, or not fully saturated with oxygene.
Nitro-Muriates	Salts formed by nitric and muriatic acids with different bases, the nitric being in the greater proportion.
Nitro-Muriate of Gold	A solution of that metal by nitro-muriatic acid, formerly called aqua regia.
Nitro-Muriate of Tin	A solution of that metal by nitric and muriatic acids, called *spirit*, by scarlet dyers.
Oxides (*metallic*)	Metals in union with oxygene, formerly called calces.
Oxygene	The basis of pure or vital air, or the aërial acidifying principle.
Oxymuriatic Acid, or *Chlorine of Davy*	The dephlogisticated marine (or muriatic) acid of Scheele, supposed by Berthollet to be muriatic acid combined with oxygene.
Phosphates	Salts formed by phosphoric acid with different bases.
Phosphate of Tin	A combination of that metal with phosphoric acid.
Potass, or *potash*	Caustic vegetable alkali.
Prussic Acid	The colouring matter of Prussian blue.
Prussiates	Combinations of the Prussian colouring matter with different bases.
Pyroligneous Acid	The empyreumatic acid obtained by distillation from wood, &c.
Pyrolignites	Combinations of the pyroligneous acid with different bases.
Soda	One of the fixed alkalies in a caustic state—the basis of common or sea-salt.
Substantive Colouring Matter	That which requires ri bso on samordant to give it lustre and permanency.
Sulphates, or *Sulfates*	Salts formed by sulphuric, or sulfuric, acid with different bases.

Sulphate of Alumine	Common alum.
Sulphate of Copper	A combination of that metal with sulphuric acid—blue vitriol.
Sulphate of Indigo	A solution of indigo by sulphuric acid.
Sulphate of Iron	A combination of that metal with iron, called green vitriol or copperas.
Sulphate of Zinc	A combination of zinc with sulphuric acid.
Sulphure, or Sulphuret of Antimony	A combination of that metal with sulphur—crude antimony.
Tannin	Vegetable matter by which skins are tanned or changed to leather.
Tartrites	Combinations of tartaric acid with different bases.
Tartrite of Alumine	Tartaric acid united to the earth of alum.
Tartrite of Tin	Tartaric acid in union with tin.

INTRODUCTION,

CONCERNING THE

ORIGIN AND PROGRESS

OF

DYEING AND CALICO-PRINTING.

THE Great Author of Nature having allotted and employed colours, to distinguish and adorn the various productions of his power, wisdom, and goodness, has also endowed some animals, and particularly man, not only with perceptions of the differences of colours, but also of the beauty arising from them, and their various combinations: and, in consequence of these perceptions, mankind, even in the rudest states of human existence, have been disposed to admire and desire ornaments, depending on gaudy and varied colours; which, in the state of naked savages, they have generally applied to their skins, and afterwards to their garments, when they had approached so far towards civilization, as to manufacture and wear clothing.* From these motives,

* A confirmation of this observation may be found in the 1st chapter of the 22d book of Pliny's Natural History, in these words: "Equidem et formæ gratia ritusque perpetui, in corporibus suis aliquas exterarum gentium uti herbis quibusdam, adverto animum. Illiunt certè aliis aliæ faciem in populis barbarorum fœminæ maresque etiam apud Dacos et Sarmatas corpora sua inscribunt. Simile plantagini glastum in Gallia vocatur: quo Brittanorum conjuges narusque toto corpore oblite; quibusdam in sacris et nudæ incedunt, Æthiopum colorem imitantes."

and the rude trials induced by them, even in remote ages, the arts of dyeing and calico-printing undoubtedly originated.

It will appear in the following chapters, that colouring matters are of two very distinct classes; one, which requires no basis, or *mediating* substance, to fix it upon other objects, and which I have, therefore, denominated *substantive* colouring matter; and the other, whose durability* depends chiefly, if not exclusively, upon the interposition of some basis, and which, for that reason, I have called *adjective* colouring matter; and as dyes of the latter class, by being the most numerous, would naturally present themselves in the greatest abundance, and be applied without any means to render them permanent, (because it would require numerous trials, and a concurrence of many fortunate accidents, to discover the use of any such basis) we may reasonably conclude, that most of the stains or colours first applied to wool, linen, or cotton, would have been fugitive. This, doubtless, was true of those which the Gauls are said by Pliny to have dyed from herbs;† as it has been of those

* This is not always completely true in regard to *wool*, which is capable of attracting some few of the *adjective* colouring matters, particularly those of madder, galium, and cochineal, so as thereby to acquire tints of some durability, *unassisted by any basis;* but the colours so obtained will be much less durable, and much more deficient in brightness, than they would have if dyed upon a suitable basis. But, in regard to linen or cotton, it may be observed, that they have no such attraction for *adjective* colouring matters, and are, therefore, incapable of being dyed by them, without the aid of a basis.

† "Transalpina Gallia *herbis* Tyrium atque conchylium tingit, omneisque alios colores: nec querit in profundis murices, seseque objiciendo escam, dum præripit, belluis marinis, intacta etiam ancoris scrutatur vada, ut inveniat per quod facilius matrona adultero placeat, corruptor insidietor nuptæ." Lib. xxii. c. 2.

Hero-

which, in later times, have been seen among the uncivilized inhabitants of recently discovered islands and countries: and we may, therefore, consider the discovery of these bases, (denominated mordants by the French) and especially that of *alum*, (which is of all others the most *generally useful* in fixing adjective colouring matters,) as being a most important event in the history of dyeing; though it is now impossible to ascertain either the time or place at which this discovery was made.

Beckman, in the Gottingen Memoires, and more recently in the first volume of his History of Inventions, has endeavoured to maintain, that the alum of the ancients, *was not*, like that of the moderns, a combination of sulphuric (or vitriolic) acid, with that white argillaceous earth, now called *alumine*,* (or alumina,) but a combination of that acid with either iron or copper, or perhaps zinc, and constituting those substances which were afterwards, and, until very lately, called green, blue, and white *vitriols;*† and in support of this his

Herodotus, indeed, as an extraordinary fact, mentions a people living on the borders of the Caspian sea, who, by bruising the leaves of a particular tree, and mixing them with water, obtained a colour, by which they afterwards painted upon their garments the figures of animals, &c.; which figures water could not afterwards remove. Book Clio, c. c. iii.

* This is not a complete description of alum, which, in fact, is a *triple* salt, (as seems to have been first discovered by Margraaff,) for the combination of sulphuric acid with alumine will not crystallize, without an addition of either potash or ammonia. According to Vauquelin, 100 grains of alum consist of 30.52 of acid, 10.50 of alumine, 10.40 of potash, and 48.58 of water.

† When the term of *vitriol* was first used is not known. Beckman could find it in no writer older than Albertus Magnus, who says, "Viride etiam quod a quibusdam *vitreo* leum vocatur." Agricola and Vossius conjecture, that it was suggested by the

opinion, he alleges, that the Greek and Roman authors, particularly Dioscorides and Pliny, mention no other than *native* alum, as being then known; that alum crystallized like the modern, is but seldom produced spontaneously; and that no mention can be found in any ancient writer, of the existence of any alum work, excepting that in Spain, noticed by Pliny, and which had for its object the crystallization of a sulphate of either copper or iron. He alleges, moreover, that every thing stated by ancient writers concerning their alum, is applicable to the metallic sulphates, since called vitriols. But this *last* allegation at least, is not correct, as may be seen by recurring to Pliny's 35th book, chap. xv. intitled, " De sulphure, *alumine*,* et generibus corum, &c." in which he says, there are many kinds of alum: " Plura et ejus genera:" that of these, the island of Cyprus affords two; one *white*, and the other black; and that though their colours do not differ so much, *their uses are very opposite;* the white alum being of the *greatest utility* for dyeing upon *wool*, *clear* and *light*, or bright, colours; as, on the contrary, the *black* is, for dyeing *brown* and *dark colours:* " in Cypro candidum et nigrum, exigua coloris differentia, cum sit *usus magna;* quoniam inficiendis *claro* colore lanis candidum liqui-

likeness of these crystallized sulphates to glass; to which, indeed, Pliny had long before compared them, in the 12th chapter of his 34th book; where, after having described the manner in which the atramentum sutorium, (sulphate of iron,) was made to crystallize upon ropes suspended over water, which held iron in solution, so that one end of each was immersed therein, he says, " *vitrumque* esse creditur."

* Beckman supposes that, excepting Columella, Pliny is the oldest writer, in whose works the term *alumen* has been found, and that its derivation is unknown. He then asks, whether it may not have come from Egypt, with the *best* sort of alum?

dum, que utilissimum est, contraque *fuscis* aut *obscuris* nigrum." He adds, that they were all obtained by natural exudations from the earth; in Spain, Egypt, Armenia, Macedonia, Pontus, and Africa; and in the islands of Sardinia, Melos, Lipara, and Strongyle; and that of all these the *best* simply is that which comes from Egypt, and next to this, that of Melos. He afterwards proceeds to notice, separately, five several sorts, mentioning the Greek names of four of them, viz. phormion, paraphoron, schistos, (called also trichitis and chalcitis,) and strongyle. His last or fifth species was in great estimation, and called melinum, because it came from the island of Melos; and he finally observes, that the different kinds of alum were all possessed of an astringent property, which had obtained for them their common Greek appellation, (*στυπτηρια.*)

That some of the several matters here mentioned by Pliny, under the general name of alum, consisted principally of iron, must be admitted: because, in addition to other reasons, he intimates that *two* of them produced a black colour with galls, and the peels of the pomegranate; and there are grounds also for believing, that one of them was a sulphate of copper. But I can discover no sufficient reason in this, or in any other part of his work, for believing, that Pliny did not also, under the name of alum, include a *sulphate of alumine*, not, perhaps, *crystallized* like our alum;* but in such a

* According to Berthollet, there is a mine of alum at Solfatara, near Naples, which, in the form of a white earth, contains alum, formed by the action of the sulphureous acid disengaged by the heat of the volcano, upon the argillaceous matter evolved by it. There, the alum requires only to be dissolved and crystallized. From a mine like this, or its earth, the good effects which Pliny ascribes to the white alum of Cyprus might be readily obtained. The famous alum mines of Tolfa, near Civita-Vechia, are still

state of purity, especially in regard to iron, as would enable it to produce the *clear* and *lively* colours for which Pliny states one of his alums to have been highly useful; and which the sulphates of iron and copper, would not have produced; nor that of zinc, (were it even certain that the ancients had ever employed it for dyeing,) unless, (which is not credible,) they possessed it in a state of much greater exemption from iron, than we find it even at this time.

The single fact of their (I mean the Greeks and Romans) having been able, long before Pliny wrote, to dye from the *kermes*, that beautiful red, or *coccinean* colour, which afterwards took the name of *scarlet*, and obtained the highest degree of estimation, is alone sufficient to prove that they must have possessed alum in some degree of purity at least, since it is known and admitted that for dyeing, they were wholly ignorant of the use of tin, the only other basis by which the colour in question could have been produced. Indeed, the kermes would have afforded nothing but a black dye with any preparation of iron; and nothing better than a dark brown with any preparation of copper.

Beckman says, (vol. i. p. 292 of his History of Inventions, translated by Johnston,) that "when our alum became known, it was considered as a species of the ancient; and as it was purer, and more proper to be used on most occasions, the name of alum was soon appropriated to *it* alone. The kinds of alum, however, known to the ancients, which were real vitriols, maintained a preference in medicine, and for *dyeing black*." But much of this appears to me absolutely incredible,

purer, according to the accounts of Monnet, Bergman, and Vauquelin, by each of whom they were analysed; but *there* the mineral requires torrefaction.

as persons who had been acquainted with the alum of the ancients, would not, when that of the moderns was made known to them, have considered it as a species of the ancient, unless there had been some *cause* for doing so; and they never could have supposed that there was cause to consider our sulphate of alumine as a species of the ancient alum, if the latter had been so *peculiarly* deserving of estimation for *dyeing black;* or if, at least, one kind of it had not been suited to dye the *very different colours* which the sulphate of alumine is *alone* able to produce. To the dyer, no two substances could have appeared so opposite or dissimilar; and there were, therefore, no two substances which he would be so little disposed to confound; and to confound in a manner so extraordinary, as that of giving the old name of alum exclusively to a supposed *new and very different substance*, and inventing a *new* name (that of vitriol) for the metallic sulphates, which he (Beckman) supposes to have before exclusively borne the name of alum. There was *then*, nothing in the name which could afford any motive for this change, if we suppose, with him, that it had for so many ages been appropriated exclusively to the sulphates of iron, copper and zinc; and it would in that case have been much more natural and convenient, to have allowed the latter to retain the name by which they had been so long distinguished, and to have invented a *new* name for the supposed *new* production. The truth seems to be that, notwithstanding the ignorance of the barbarous ages, the inconvenience of calling substances, possessing the most opposite properties, by one common name, had been generally felt; and that to obviate this inconvenience, the name *vitriol*, as distinguishing the metallic sulphates, had been gradually adopted, and that of alum had been appropriated exclusively to the (perhaps im-

pure) sulphate of alumine; and that when this came to be introduced from Syria in a crystallized form, it obtained in Italy, (for reasons to be hereafter considered,) the *additional* appellation of *rocca*, or roccha, to distinguish it from that which had before been in common use; and hence the French name of alun de roche, and the English of rock, or roach alum.

Were it ascertained that the Greeks and Romans, at the times of Dioscorides and Pliny, were wholly unacquainted with crystallized sulphate of alumine, even in that which Beckman calls the *best sort*, brought from Egypt, I should think it highly probable, notwithstanding, that such alum existed, and was then employed, among the people of Hindostan and other parts of India; where, (as will appear by facts stated between pages 257 and 260 of this volume,) the arts of dyeing and calico printing had been practised more than two thousand years ago, exactly in the same manner, and with the very same means, (particularly crystallized alum and acetate of iron,) which were found to be in common use among them, when the Portugueze first reached that part of Asia, by sailing round the Cape of Good Hope; and without which, the art of calico printing could never have existed. It will also appear, that the Egyptians, before the time of Pliny, had practised this art of calico printing, and had borrowed therewith some productions necessary for the exercise of it, from Hindostan;* and it may be presumed, that crystallized alum,

* Among these, (as is proved at p. 186, &c. of this volume,) was that most wonderful production, *indigo*, which seems to have originated among the Hindoos. The people of other countries had, indeed, found out ways to communicate substantive blue colours from different plants, and particularly from woad, or the isatis tinctoria, Linn., but not to precipitate and collect the colouring matter in a dry solid form, like indigo. *This* the people of Hindostan had not

which is even now sometimes imported from India to this country, (and which has been in use *there* during so many centuries, that no means exist for ascertaining when its use began,) would, from its indispensable necessity, have been carried thence with other dyeing drugs to Egypt; and to me it certainly does not seem improbable, that this was that sort of Egyptian alum, which Pliny mentions as being in greater estimation than any other. Beckman, indeed, says, p. 291, "It is well known that *real* alum is reckoned among the exports of Egypt at present; but, (he adds,) I am acquainted with no author who mentions the place where it is found or made, or who has described the method of preparing it." Whether the Egyptians, after obtain-

only effected, but they had afterwards done *that* which must have been more difficult; they had discovered the means of *dissolving* indigo when so prepared, in ways the most suitable for applying and fixing its colour permanently on the substances to be dyed with it; which the Greeks and Romans do not appear to have ever performed, though they knew how to powder indigo, and apply it as a paint.

From the fifth volume of that extensive work, entitled, "Memoires concernants l'Histoire, les Sciences, les Arts, les Moeurs, &c. des Chinois," it appears that wool was never worn in China but as a substitute for fur, and that cotton and silk, being the only substances ever dyed by the inhabitants, received all their colours from vegetable tingent matters; that these colours were principally red, blue, violet, and what is called a woad colour; and that, under the three first dynasties, the business of dyeing was chiefly practised by the female part of each family, for its own particular use: and it, probably, continued to be practised without any thing like principle or science until near the end of the seventh century, when the Chinese, discarding their own, borrowed the arts and means of dyeing which were then in use among the Indians and Persians: and it is said, that alum and copperas, which the Chinese did not use before, were among the means so borrowed; a fact which renders it probable that there was little, if any thing, in the Chinese art of dyeing, of which the loss need now be regretted.

ing alum from India, had, by doing so, discovered the means of preparing it in their own country; or whether they continued to obtain it from India, or were afterwards supplied with it by the inhabitants of any of the intermediate countries, who might have acquired this knowledge from the Hindoos, I know not; but it seems evident that Egyptian alum, however it may have been obtained, had been long and far famed, since Herodotus (in a passage which Beckman has quoted from his second book, c. 180.) relates, that when the people of Delphos solicited a contribution for re-building their temple, which had been burnt, Amasis, king of Egypt, sent them a thousand talents of *alum*.

Beckman supposes that crystallized sulphate of alumine, similar to our alum, was, undoubtedly, first made in the East; and that it was not known in Europe before the end of the twelfth century; and if this be true, it seems probable that the knowledge of it, and of the methods of bringing it into a crystallized form, had gradually spread from Hindostan, through Persia, and the intermediate countries, to Syria, where it was made use of before the overthrow of the Greek empire; and whence it was confessedly brought to Italy in the fourteenth century.* Beckman has given us extracts from the writings of three respectable historians, viz. John Jovianus Pontanus, Peter Bizaro, and Augustin Justinian, who all relate, that about the year 1460, Bartholomew Perdix, (by some called Pernix,) a Genoese

* Beckman mentions alum works as existing near to Constantinople, in the fifteenth century; and also one of great celebrity in the neighbourhood of Smyrna; whence the Italians procured alum and other dyeing drugs. He also mentions an Italian treatise written by Francisco Balducci, about the middle of the fourteenth century, by which it appears that the Italians were then acquainted with no other than Turkish alum.

merchant, who had become acquainted with the preparation of alum in Syria, when returning thence to Italy, happened, at the island of Ænaria, now called Ischia, or Hiscla, to observe large alum stones among the substances which had been thrown up, more than one hundred years before, in consequence of the eruption of a destructive volcano there; and that, having calcined some of these stones in a furnace, he extracted from them excellent alum. But these historians all assert, contrary to the supposition of Beckman, that he, (Perdix,) in doing this, *only* revived and brought *back to Italy* an art which had, with many others, been lost amidst the darkness which, during several centuries, prevailed over the western empire; which art he had himself learned at the city of *Rocca*, in Syria. Beckman says, he had at first supposed, that this city might have been Rocca, on the Euphrates; but he had afterwards thought it more likely to have been *Edessa*, sometimes called Rocha, &c., and also Roccha; and that, though the latter is considered as being in Mesopotamia, the supposed limits of Syria might, at that time, have extended thus far. From this city of Rocca, Beckman supposes, with Lisbnitz and others, that the best crystallized alum obtained in Italy the additional epithet of Rocca; while some persons, and among them Julius Cæsar Scaliger,* think it to have been derived from the Greek name of a rock, alum being obtained, by boiling, from stones; and it seems to have been this opinion which caused the appellation to be translated into Latin, by the words *alumen rupeum*, and into French by those of alum de Roche; and there are again

* "Vulgo audis *alumen rochæ*, que Græca vox maximæ Europæ servit parti ad rupem significandum." Exotic. Exercitat. Francf. 1612. 8vo. p. 325.

some, who imagine, that this name was suggested, and occasioned more immediately, by the alum *rocks* of the famous *mines* at *Tolfa*, near Civita-Vechia, from which alum of the purest quality has been longer extracted than from any other mine now subsisting in Europe; and these were discovered by John de Castro, a few years after Perdix had begun to produce alum from the stones which he found at Ischia. Of this memorable discovery, which happened during the pontificate of Pius the Second, that pope has given a circumstantial account; for which see "Pii Secundi Comment. rerum memorab. quæ temp. suis contingerunt," &c. Francofurti, 1614, fol. p. 185.*

* Beckman has extracted this account, of which the following are the principal parts, viz.

This John de Castro, "being fond of travelling, had resided some time at Constantinople, and acquired much wealth by dyeing cloth made in Italy, which was transported thither, and committed to his care, on account of the abundance of *alum* in that neighbourhood. Having by these means an opportunity of seeing daily the manner in which alum was made, and from what stones, or earth, it was extracted, he soon learned the art. When, by the will of God, that city was taken and plundered, about the year 1455, by Mahomet II., Emperor of the Turks, he lost his whole property; but, happy to have escaped the sword of these cruel people, he returned to Italy, after the assumption of Pius II., to whom he was related, and from whom he obtained, as an indemnification for his losses, the office of commissary-general over all the revenues of the Apostolic Chamber, both within and without the city. While in this situation, he was traversing all the hills and mountains, searching the bowels of the earth; he at length found some *alum* stones in the neighbourhood of *Tolfa;* and having made experiments by calcining them, he obtained *alum:* and repairing to the Pontiff, said to him, "I announce to you a victory over the Turk. He draws yearly from the Christians above three hundred thousand pieces of gold, paid to him for the alum with which we dye wool of different colours, because none is found here, but a little at the island of Hiscla, formerly called Ænaria, near Puteoli, and in the cave of Vulcan at Lipari, which having been exhausted by the

The wealth which the pope obtained from the discovery and working of the mines at Tolfa, encouraged and produced similar undertakings in other parts of

Romans, is now almost destitute of that substance. I have, however, found seven hills, so abundant in it, that they would be almost sufficient to supply seven worlds. If you will send for workmen sufficient, and cause furnaces to be constructed, and the stones to be calcined, you may furnish alum to all Europe; and that gain which the Turks used to acquire by this article, being thrown into your hands, will be to him a double loss, &c.' These words of Castro appeared to the pontiff as the mere result of idle dreams. He, however, employed skilful people, who found that the stones really contained alum; but least some deception might have been practised, others were sent to the place where they had been found, who met with abundance of the like kind. Artists, who had been employed in the Turkish mines in Asia, were then brought from Genoa; and these, having closely examined the nature of the place, declared it to be similar to that of the Asiatic mountains which produce alum; and, shedding tears for joy, they kneeled down three times, worshipping God, and praising his kindness in conferring so valuable a gift on our age. The stones were calcined, and produced *alum more beautiful than that of Asia, and superior in quality.** Some of it was sent to Venice and to Florence; and being tried, was found to answer beyond expectation. The Genoese first purchased a quantity of it, to the amount of twenty thousand pieces of gold; and Cosmo, of Medicis, for this article, laid out afterwards seventy-five thousand. On account of this service, Pius thought Castro worthy of the highest honours, and of a statue, which was erected to him in his own country, with this inscription:—' To John di Castro, the inventor of alum;' and he received, besides, a certain share of the profit; immunities and a share also of the gain, were granted to the two brothers, lords of Tolfa, in whose land the aluminous mineral had been found. This accession of wealth to the church of Rome was made, by the divine

* This alum continues to be known under the name of *Roman* alum, and esteemed above all others; principally because it contains but about half as much *ircn* as most other alums: the latter, however, may be rendered equally pure and valuable, by calcining, then dissolving, and afterwards re-crystallizing them. Stahl, Newman, Pott, and other eminent chemists, considered *alumine* as a calcareous earth, and not as being an earth, which it is, *sui generis,* nearly related to clay, but differing from it.

Italy, particularly at Volterra, in the district of Pisa, though their success was greatly obstructed by the obstacles which the pope contrived and employed against them, in order that he might monopolize all the benefits to be derived from the manufacture and sale of alum; of which he raised the price so exorbitantly, that alum procured from the Turks was found much cheaper than that of Tolfa, and, therefore, employed. But to obviate this interference, the pope pretended to devote the revenue produced by his alum works to the defence of christianity against the Turks, and menaced all, who should act so unchristianly, as to purchase, or procure, alum from these infidels, with excommunication; which prohibitions were renewed by several of his successors.

It appears from Biringocci's Pyrotechn. p. 31, that the first alum work established *out* of Italy, subsequently to the discovery of those of Tolfa, was that of Almacaron, near Carthagena, in Spain; whence, as is stated in Guicardini's description of the Netherlands, large quantities of alum were brought to Antwerp, in the early part of the sixteenth century.

In England the first alum work was that of Gisborough, in Yorkshire, begun near the end of Queen Elizabeth's reign, upon lands belonging to Sir Thomas Chaloner, who secretly procured workmen from the alum works at Tolfa, no person in England then knowing how to produce it. This seduction of his workmen so enraged the pope, as we are told by Pennant, in his Tour to Scotland, that his holiness endeavoured to frighten and recall them by curses, or anathemas, in the *very form left us by Ernulphus*.

blessing, under the pontificate of Pius II.; and if it escape, as it ought, the hands of tyrants, and be prudently managed, it may increase; and afford no small assistance to the Roman pontiffs, in supporting the burthens of the Christian religion."

The intimate and important connection of the history of alum with that of dyeing, has induced me to state these facts, which I have chiefly derived from Beckman's first volume; though I have not thought it right to adopt some of his conclusions on this subject.

To discover by retrospection all the ways and means by which an art like that of dyeing has been improved from its earliest and most simple beginnings, in different parts of the world, must now be impossible; because, among some nations, it, undoubtedly, would have been considerably advanced, by fortunate accidents and instructive observations, long before they had learned to write histories and record facts; and, indeed, almost all the progress which had been made in dyeing, until within a few years, must have resulted from such causes; depending, as it does, for its principles upon chemistry, which was by much too defective to afford any considerable assistance, either to practical dyers, or speculative men, who might have wished to study and improve the art; and, therefore, it happened, as might have been expected, that the *practice* of dyeing had, by the fortuitous discoveries of great numbers of individuals employed in it, been carried so far before the *theory*, that the latter was as little capable of *explaining*, as it had been of *suggesting*, the most beneficial effects produced by it; and this, probably, was at least one reason why dyeing was so much neglected among the philosophers of Greece and Rome, though they highly esteemed the arts of painting, sculpture, &c.

Notwithstanding the great importance of alum in dyeing, it is not probable that mankind, with their natural disposition to admire gaudy colours, and seek personal distinctions, should have delayed the application even of adjective dyeing matters, to their clothing, until they had become acquainted with alum and its effects, in

raising and fixing the colours afforded by these matters. Such an acquaintance would not, in the ordinary course of events, be acquired, until some progress had been made in civilization;* and there are many facts to prove that, in much ruder states of society, men have attempted to dye their clothing;† and as these attempts would have proved more successful upon *wool* than upon linen, or cotton, by reason of the greater *affinity* of the former to some adjective colouring matters, (as lately noticed,) we may conclude, that in climates which required clothes of wool, the dyeing of these would have been practised much earlier than that of linen or cotton.‡ And, accordingly, Pliny mentions *dyed linen* as

* Clavigero, in his history of Mexico, pretends that the Mexicans used the earth of alum to produce certain colours: that, after grinding and dissolving the aluminous earth, which they called *tlalxocotl*, they boiled it in earthen vessels, and then, by distillation, extracted the alum pure, white and transparent; and that, before they hardened it entirely, they divided it in pieces to sell in the market. To a chemical reader this will sufficiently discover the ignorance of the historian in regard to the effect of distillation, &c. What foundation this account may have had in other respects I know not.

† Of the nature of these attempts, and the value of some at least of the colours produced by them, we may judge, by the mention which Pliny has made of a purple dyed for the clothing of inferior people among the Gauls, from "vaccinia;" by which either the ripe privet, or the whortle berries, are supposed to have been meant. See lib. xvi. c. 18. He also mentions *violets* as being used to produce a purple.

‡ Uncivilized nations appear, in some instances at least, to have found means to increase this *affinity*, particularly by the use of vegetable acids. The savage tribes of North America, had long been accustomed to dye certain animal substances, such as hair, feathers, and porcupine quills, of bright *red* and *yellow* colours, whilst they were wholly unacquainted with the use of alum; and having been informed, that the red, so dyed, was produced from the galium tinctorum, and the *acid* berries of the scarlet sumach, lately mentioned, I made trial of them upon broadcloth *without alum*, and

having been seen for the *first* time, in the fleet with which Alexander the Great had navigated the river *Indus*, when his captains, in skirmishing with the Indians upon its banks, to their astonishment suddenly changed the ensigns of their vessels, and displayed flags of various colours wavering in the wind.* It must, however, be confessed that, according to Pliny's account, the dyeing even of woollen clothes had, at that time, made but little progress, at least in regard to the finer colours; for, in the eighth chapter of his twenty-first book, after declaiming against the luxury of his cotemporaries, in

produced a red colour, inclining to the orange, of considerable brightness, which, being exposed with a red less inclining to the orange, which I had dyed also from the roots of galium tinctorum only, but upon broadcloth, prepared as usual with alum and tartar, I found, at the end of two months, that, though the latter had suffered least, the other with sumach berries was much better and more lasting than I had supposed it possible to produce without some basis. I have since been informed, that the acid juice of the crab apple is sometimes employed by the tribes in North America for the same purpose; and that professor Woodhouse, of Philadelphia, supposes himself to have discovered alumine in the very acerb fruit of the diospyros virginiana, or persimmon tree, which, if this supposition be well founded, may be expected to produce still better effects as a mordant for dyeing, than either of the acids before mentioned; unless the latter, as some have supposed, should also contain alum. Indeed, Loureiro (tom. i. p. 315.) has described a tree, under the name of decadia *aluminosa*, of which he says the bark, and more especially the dried leaves, are in great use among the dyers of Cochinchina, to *exalt* and *fix* their colours. "Magni usus sunt infectoribus indigenis in tingendis telis quarum colores decocto illorum nitidé *exaltantur* et *firmantur*." This statement, joined to the specific name of *aluminosa*, appears to indicate that the bark and leaves of this tree either contain *alumine*, or are thought capable of answering the purposes of alum as a mordant.

* "Tentatum est tingi *linum*, quoque et vestium insaniam accipere, in Alexandri Magni primum classibus, *Indo* amne navigantis, cu[illegible]u es ejus et prefecti certamine quodam variassent insignia navium: stupueruntque littora, flatu versi coloria implente."

wearing clothes dyed of colours which *emulated* those of the *finest natural flowers*, he observes, that none of these flowery colours ("flores") were in use during the life of Alexander the Great; though, says he, nobody doubts of their having been borrowed by the Romans from the Greeks; for how else, he asks, should the names which they still retain in Italy, have been all Grecian, "a Græcis tamen repertos quis dubitet; non aliter Italia usurpante nomina illorum?"

Probably, the companions of Alexander, when he invaded Persia and India, became acquainted with the rich dyes of those countries; and afterwards made some, at least, of them known to the Greeks, among whom, as well as among the Romans, the wearing of *undyed clothes*, (which Pliny has denominated "*panni nativi coloris*,") had been immemorially practised by the great mass of people.* We are not, however, to understand that dyed clothes were not in much higher estimation than the undyed, as soon as they were made known, for this, undoubtedly, was the fact; but they were too costly to be used by any but the rich and great, or for the service of religion, or upon extraordinary occasions. See Exodus, chapters 26, 28, 38, and 39. See also Plutarch, de Iside and Osiride, c. 78, where he tells us, that the robes or sacred vestments of *Isis*, were of *various* colours; but those of *Osiris* were of *one bright* colour. Juno, Venus, and Proserpine, were by the ancient poets commonly represented as being robed in purple; and we are told, in the 37th chapter of Genesis, that Jacob "loved Joseph more than *all* his children, because he was the son of his old age; and he made him

* As these undyed clothes often wanted cleaning, this operation gave employment to a description of people called *fullones*, who were properly *scourers*, though the clothes would naturally be thickened or *fulled*, in some degree, whilst in their hands.

a *coat of colours:*" a distinction which caused Joseph to be hated by his brothers; and afterwards to be sold by them, and carried into Egypt.

Of the substantive colours known in Greece, and at Rome, two (highly deserving of our notice) were the celebrated purple obtained from the murex and buccinum, and the blue procured from indigoferous plants, particularly the woad, (glastum or isatis tinctoria): of these, and of their connection with the history of dyeing, most ample and interesting accounts will be found, in the 4th and 5th chapters of the first part of this work. Another plant, by the Romans called *fucus*, and which appears to have been no other than that species of lichen which is now called *orchall*, was in such general use among the latter, for dyeing a beautiful, though not durable purple, that the name of fucus, came at length to be often used as signifying generally *a dye*. Of this also a sufficient account will be found at page 216 of this volume.

In regard to the adjective colouring matters for which alum or aluminous earths and other mordants were employed by the ancients, I must observe, that it seems difficult to give a complete account of them: though we have reason to conclude, that the kermes (or coccus illicis) and madder (rubia) were by much the most important: of these also, and of their connection with the history of dyeing, sufficient accounts will be found in their proper places. To these may be added the roots of anchusa tinctoria, or alkanet, the genista tinctoria, or dyer's broom, (mentioned by Pliny, xvi. c. 18.) gall-nuts, pomegranate peels, alder bark, the rinds of walnuts, the bark of the walnut tree, and the pods of the Egyptian acacia; but of the particular methods in which these were employed, or of the basis or mordants used with them, no information worthy of being here particu-

larly noticed has been transmitted to us, either by Greek or Latin writers. And, indeed, almost all the knowledge which the Greeks and Romans had obtained from others, or acquired by their own industry, on this subject, appears to have been lost about the fifth century, when, as M. Berthollet has observed, scarce any traces of science or humanity were left in the western empire. A few sparks of the former did, indeed, remain in Italy, where they were in some degree rekindled, by occasional accessions of knowledge, and of Greek artists obtained from the east, in consequence of the crusades; and also, from the various importations made by the Venetians, of oriental productions and manufactures; which, by affording new materials, and new objects of imitation, assisted in exciting and directing that industry which had so long been dormant in the west of Europe.

Italy may, therefore, be considered as the *cradle* in which a feeble remnant of the knowledge of dyeing, as exercised by the Greeks and Romans, was nourished and invigorated, so as, with the *new* dyeing drugs since obtained from India and America, (which will be hereafter noticed,) and with the various subsequent acquisitions of chemical and other knowledge, to have attained a state of improvement, greatly exceeding all former expectation.

From Italy some knowledge of dyeing, limited as it was, spread itself gradually to France, Spain, and Flanders, whence king Edward the Third, of England, procured *dyers;* and in 1472, a company of these artists was incorporated in London.

The Germans, as Bischoff informs us, were slow in acquiring and practising the art of dyeing; excepting only that of *black*, which was their dress or gala colour;

and excepting *browns*, which were generally wore by the monks, and the common people.

In France a division was established at a very early period, between the dyers of *lasting* colours, who were denominated "teinturiers en *bon teint*," and the dyers of fugitive colours, or those "en petit teint;" and the former were prohibited from using, or having in their possession, the dyeing drugs employed by the latter. A similar distinction was also established in Italy, as Bischoff states, on the authority of a French ordinance of November 17, 1383.

The first Italian account of the processes used in dyeing, as Bischoff, and after him Berthollet, have informed us, was published at Venice in 1429, under the title of "*Mariegola dell' Arte dei Tentori*," of which a second edition appeared in 1510. But the imperfections of this work, induced John Ventura Rosetta, overseer of the arsenal at Venice, to undertake a work less defective; and the better to execute his undertaking, he travelled over different parts of Italy, and some other countries, to acquire information; from which he composed, and in 1548 published, under the assumed name of *Plictho*, a collection of descriptions of the operations of dyeing, as then practised, which Bischoff considers as the foundation and principal cause of many subsequent improvements in this art:* though Hellot has mentioned it as deserving but little notice.

* The title of this work was "Plictho dell' Arte dé tentori che insegna tenger panni, tele, banbasi, e sede si per l'arte magiore, come per la commune. Vinezia, 1448, 4to." Or Plictho's Art of Dyeing, which teaches how to dye cloth, linen, cotton and silk, of durable, as well as false, or ordinary colours, &c.

Berthollet has remarked, that there is no mention in this work, of either cochineal or indigo; whence he infers, that neither of these important drugs had then been employed for dyeing in Italy; an inference which, though probably just, seems extraordinary, con-

Of the important changes, and rapid advancement, which were produced in dyeing after, and by the discovery of new and valuable colouring matters, and also of new bases or mordants, (particularly that of tin,) sufficient accounts are given in the course of this work, and to these I must refer, to avoid improper repetitions.

The first or earliest book, which I have been able to discover in the English language, relating in any considerable degree to the art of dyeing, is a thin and small quarto volume, (now before me,) in black letter, intitled "A Profitable Booke, declaring divers approved remedies to take out spots and stains, in silkes, velvets, linnen and woollen clothes; with divers colours how to *die* velvets, and silkes, linnen, and woollen, fustian, and thread: also to dress leather and to colour felles."—"Taken out of Dutch, and Englished by L. M. Imprinted at London, by Thomas Purfoot, dwelling within the New Rents in S. Nicholas Shambles, 1605."

The instructions contained in this last volume, relate principally to the use of indigo, (which is called *flora* or floray,) woad, madder, (particularly the *crap*,) Brasil wood, weld, safflower, gall-nuts and alder bark; once or twice kermes and lac are mentioned; but not cochineal. These instructions seem to be founded chiefly upon the practices of the dyers in Flanders, where the art at that time was making considerable progress; but as black was the colour in most general use, the receipts, if I may so call them, for producing it, are in number equal to almost all the others. After this, nothing seems to have been done in this country to inform or assist practical dyers, until the year 1662, when the Royal Society, then recently formed, at their meet-

sidering the facts which will be found in the fifth chapter of the first part, and the third chapter of the second part of this work.

ing on the 30th of April, desired Mr. Haak to translate into the English language the work which, more than half a century before, had been published in Italy, under the name of Plictho, (though this has never been done;) and, on the same day, Sir William Petty, one of its earliest and most active members, in consequence of a previous request from the Society, brought in "An Apparatus to the History of the Common Practices of Dyeing," which was afterwards printed in Dr. Spratt's History of the Royal Society, and seems to have been the first *original*, though summary account published in the English language, of the means and operations used by dyers.

Nearly two years afterwards, viz. March 30, 1664, the Hon. Robert Boyle presented to the Royal Society his "Experiments and considerations, touching Colours;" and, on the 10th of August following, it was ordered by the society, "that the way of *fixing colours* should be recommended to Mr. Howard, Mr. Boyle, and Dr. Merritt." These, and especially the two first, were among the most distinguished members of the society; but it does not appear that they were able to do any thing deserving of notice, in consequence of this recommendation, However, at a meeting of the society on the 11th of November, 1669, that very ingenious, active, and useful member, "Mr. Hooke, produced a piece of calico, stained after the way contrived by himself, which he was desired to prosecute in other colours, besides those that appeared in this piece." (Birch's History of the Royal Society, vol. ii. p. 401.) And, accordingly, on the 9th of the following month, "Mr. Hooke produced another specimen of staining with yellow, red, green, blue, and purple colours, which, he said, would endure washing with warm water and soap." But from this time it does not appear that any thing considerable

was done, for nearly the space of a century, by men of science in this kingdom, towards improving the arts of dyeing and calico printing; they being, probably, discouraged by the difficulties which, from the very imperfect state of chemical knowledge, must have occurred, in every attempt to improve upon what the dyers were able to perform, without any principle or theory.

In France, however, that great minister, Colbert, anxious to extend the commerce and manufactures of his country, turned his attention particularly to the art of dyeing, with a view to amend, as well as to obviate frauds in the practice; and calling to his assistance M. D'Albo, a set of regulations and directions were prepared and published at Paris, first in 1669, and afterwards in 1672, under the title of "Instruction générale pour la Teinture des Laines et Manufactures de Laine de toutes Nuances, et pour la Culture des Drogues ou Ingrédients qu'on emploie." This, however, was not intended merely to inform, but, as a legislative act, to control the dyers in their operations. It continued the former division of them into two classes; the one, dyers "*en grand*," who were confined to the colours deemed lasting, while the dyers "*en petit teint*," were allowed only to give those which were considered as fugitive; the drugs to be employed in each branch being also particularly specified; and the dyers in each prohibited from using, or having in their possession, any of the drugs allotted to the other. Such restraints, though intended to prevent frauds, would have operated as checks upon future improvements, if the government had not, at the same time, encouraged useful discoveries in this art, first, by offering particular rewards, and afterwards, by appointing those eminent chemists, Dufay, Hellot, Macquer, and Berthollet, in succession, to superintend, officially, the practice of dyeing in its several depart-

ments, and to cultivate those branches of chemical and other sciences, which were connected with the principles, or capable of amending the theory, of that art; and, considering the eminent benefits which have resulted from the labours of these men, there is cause to regret the want of such an appointment in this *great manufacturing and commercial nation.*

With Dufay's assistance, M. Colbert's "Instruction" was amended, or rather superseded by a new one, published under the administration of M. D'Orry, in 1737. He (Dufay) appears to have been the first who entertained just conceptions of one of the causes of the adhesion of colouring matters to stuffs when dyed; I mean that which depends on an affinity or attraction subsisting between such matters, and the fibres or substance of the dyed stuffs. He clearly perceived that without this, cloth, while in the dyeing vessel, could only acquire a degree of colour *equal* to that of the dyeing liquor, by an *equal participation* of the colouring matter dissolved therein; whereas, in fact, the cloth is often seen to exhaust, *by attracting to itself* all the tingent particles of the dyeing liquor, so as to leave it as colourless as water. He also noticed the difference in the degrees of attraction, which different substances, as wool and cotton, exert upon the same colouring matters; and which he found so great, that a skein of each having been in an equal degree subjected to the means and operations commonly employed for dyeing scarlet, the woollen yarn was found to be fully and permanently dyed of that colour, while the cotton retained all its former whiteness.* He appears, however, to have had no conception of the other and more important cause

* Observations Physiques sur le Mélange de quelques Couleurs dans la Teinture. Mémoires de l'Académie Royale, &c. 1737.

of the permanency of adjective colours, I mean that which arises from the *interposition* of a *suitable basis*, possessing a particular *attraction* both for the colouring matter and for the dyed substance, and thereby acting as a *bond of union between them:* nor did his successor, Hellot, ever approach nearer to the truth on this subject. He, (Hellot,) indeed, published an excellent practical treatise on the art of dyeing wool and woollen cloths, in which the several processes were very accurately described: but in reasoning upon the facts stated therein, he adopted, and suffered himself to be grossly misled by, a frivolous hypothesis, devoid of the least foundation in truth. He fancied that he could discover, in every dyeing process, some means by which sulphate of potash (then called vitriolated tartar) might be formed; and this neutral salt not being readily soluble by cold water, nor by air or light, he conceived the whole art of dyeing to consist in first dilating the pores of the substance to be dyed, so as to procure a copious admission of colouring matter, divided by a suitable preparation into atoms, and then wedging or fastening these atoms within the pores of the dyed substance, by the small particles or crystals of this difficultly soluble neutral salt. Upon this *mechanical* hypothesis, he supposed that alum became useful in dyeing, not by the pure clay or alumine which it contains, and which alone contributes to fix any colouring matter, but by furnishing (and only by furnishing) sulphuric or vitriolic acid, to assist in forming the sulphate of potash, which was to perform this important function of wedging or fastening the colouring atoms; though, if he had brought this visionary hypothesis to the test of experiment, as might have been easily done, he would have found, not only that no sulphate of potash existed, in many of the cases where he supposed it to produce such important effects,

but also that, even if intentionally formed and employed for this purpose, it possessed no power whatever of fixing any colouring matter yet known. But though nothing could be more groundless than this theory, the learned in all countries appear to have been satisfied with it for a considerable length of time, it being always less troublesome to believe than to make experiments. The late celebrated Macquer, in a Memoir, printed among those of the Royal Academy of Sciences for 1749, mentioning Hellot and his hypothesis, says, "ce savant chimiste est le premier qui ait porté le *flambeau* de la physique, dans l'art obscur de la teinture, et qui ait rassemblé et mis en ordre, suivant les principes d'une théorie ingenieuse, les phénomenes et les opérations bizarres de cet art: il a mis les chimistes à portée de voir clair, dans ce chaos ténébreux." And afterwards, in his preface to his Treatise on dyeing Silk, published in 1763, he makes this observation: "ce seroit ici le lieu d'expliquer la maniere dont les mordants agissent dans la teinture, et de développer la cause du bon et du faux teint; mais ces objets ont été traités avec tant de segacité par M. Hellot, que je crois devoir y renvoyer le lecteur;" and even so lately as the year 1766, in an eulogium pronounced upon Hellot, in the Royal Academy of Sciences, and published with the Mémoires for that year; the secretary, after explaining Hellot's hypothesis, says, "à l'aide de cette théorie si lumineuse, on ne sera plus trompé dans la pratique de cet art, que lors qu'on voudra bien l'être."

Before this time, viz. 1748, Scheffer published a small work on dyeing, which Bergman afterwards thought worthy of being republished, with notes written by himself. It related in a great degree to the application, for the benefit of the Swedish manufactures, of the indigenous dyeing plants of that kingdom; in search of which,

Linnæus afterwards undertook his *Iter* Gothlandicum. Scheffer was thought to have made discoveries of considerable importance in dyeing; but not having been published, most of them were lost, as Bergman informs us.

Mr. Henry, of Manchester, has observed, that Mr. Keir, the ingenious translator of "Macquer's Chemical Dictionary, appears to have been the first who suspected that (in dyeing) the earth of alum was precipitated, and in this form attached to the material prepared or dyed;" and this idea, having been published, was adopted by Mr. Macquer, and farther extended in the last edition of his "Dictionnaire de Chimie," at the article "Teinture," where he seems to have formed just conceptions of the nature and uses of alum, and of different metallic solutions, as mordants, in dyeing.* This edition was published in the year 1778, and Mr. Macquer soon after announced a design of writing a general treatise on the art of dyeing, which his death, however, frustrated. Some time after Mr. Macquer's decease, Mr. Henry favoured the public with a very interesting paper, (in the third volume of the Memoirs of the Manchester Society,) "On the nature of Wool, Silk, and Cotton, as objects of the art of Dyeing; on the various

* Berthollet considers Bergman, as being the first who ascribed the fixing of colours, by dyeing, to particular affinities; and I cannot now readily ascertain dates so accurately as to decide whether he did this previously to Mr. Keir's publication of the translation of Macquer's Dictionary.

Perhaps it may be allowable for me to observe, that, in a communication which I made to the Royal Society in 1773, mentioned in the last chapter of this work, I distinctly ascribed the production of ink and the black dye to this *affinity* between iron and the colouring matter of galls, and so far, at least, I had anticipated both Kier and Bergman. The first publication by the latter, on this subject, was, I believe, in 1776.

preparations and mordants requisite for these different substances; and on the nature and properties of colouring matter, &c.:" a paper replete with useful information, and ingenious ideas, (particularly respecting the causes of the durability of what is called the Turkey red,) and which deservedly reflects great credit on the author's talents and acquirements. And in the year 1791, that most excellent chemist, M. Berthollet, who had been appointed by the government of France to succeed M. Macquer in superintending the arts connected with chemistry, and particularly dyeing, published a work of great merit, under the title of "Elémens de l'Art de la Teinture," in two volumes, which has been translated into English by Dr. Hamilton.*

Before the publication of M. Berthollet's work, I had collected most of the materials for this undertaking; and, though he has anticipated many things which I was prepared to mention, (some of which I shall notwithstanding mention in my own way,) this production afforded me great pleasure, as well as profit; because the author's superior chemical knowledge has enabled him to take just views of many intricate parts of his subject, and to reason with great solidity, as well as sagacity, upon most of the operations of dyeing. He has, moreover, enabled me to abridge my own work, by referring, as I must do, to his, for more ample information upon several topics, particularly those of fuel, the different acids, alum, the sulphates of iron, copper, and zinc, verdigrise, acetite of lead, the different alkalies, soap, sulphur, arsenic, and water, of all which he has treated so

* Since the above was written in 1794, a new and *improved* edition of the "Elémens de l'Art de la Teinture" has been published by M. Berthollet, conjointly with his son, (lately deceased,) and all my quotations from the Elements, &c., are to be understood to have been made from this *new* edition, unless the contrary be stated.

ably and fully as to leave but very little for me to add respecting any of them.

But though I have been preceded by authors of such distinguished ability as Mr. Henry and M. Berthollet, the new facts and observations which I here offer to my readers, will show that I did not find the subject exhausted. And, indeed, it is so far inexhaustible, that it probably will afford ample employment for the greatest talents and industry during many generations.

In justice to that very eminent and respectable chemist, M. Chaptal, I ought to mention that his excellent work, intitled "Elemens de Chimie," (in three volumes,) contains many ingenious facts and observations relating to the causes of the production and changes of colours, as well as to several other subjects connected with dyeing: and to these he has since made considerable additions in his most valuable work, intitled "Chimie appliquée aux Arts," in four volumes octavo, which was published soon after he had, with great difficulty, obtained permission to resign his office of minister of the interior of France, and return to his early and favourite pursuits.

M. Vitalis, of Rouen, has also recently published a small but useful work, intitled, Manuel du Teinturier sur fil et sur coton filé.

Some other works deserving of notice have also, within a few years, been published on this subject, particularly a French translation of that of Scheffer, with notes, by the celebrated Bergman; another by Pœrner, which has been translated into French from the German, and published with notes by Desmarets and Berthollet; and a third by Dambourney; but neither of these has done much towards improving the theory of dyeing. That of Pœrner contains an account of many experiments made by the author, with different dyeing drugs; but, unfor-

tunately, his reasonings upon them, and upon every part of the subject, are highly defective. Dambourney (a respectable merchant) was possessed of no chemical science, and he has done little more than give an account of the trials which he made with a considerable number of vegetable matters; few of which are likely to be ever much, if in any degree, employed by dyers.

Calico printing, though practised for many ages in some parts of Asia, seems not to have been seriously attempted in Europe, until the eighteenth century; and its progress, as well as introduction, were, for a considerable time, chiefly the result of British ingenuity and industry. Of their effects, some account will be given at p. 253 et seq. of this volume; and I shall only add here, that, about the year 1750, it was computed that fifty thousand pieces of linen and calico were annually printed in Great Britain, and chiefly in the neighbourhood of London; though, at that time, there was no calico printing in France, and the French government, to favour their silk manufactures, had prohibited, under severe penalties, the wearing of chintzes, and printed linens and cottons. In 1759, however, these prohibitions were annulled.

Eminent writers have derived the arts of dyeing and calico printing from a considerable degree of perfection, which they suppose chemistry to have somewhere attained in remote ages, though afterwards lost; and they imagine that particular processes of the art were preserved after the principles on which it was founded had been forgotten.* I am not able, however, to perceive any sufficient ground for these opinions. In fact, there

* See Mr. Henry's paper in the third volume of the Memoirs of the Manchester Society. Also Hist. and Memoires de l'Acad. R. des Sciences, &c. 1750, and 1766.

is no good reason to believe, that chemistry ever had made any such progress among the ancients, or that they ever were so much engaged in the pursuit of knowledge by *experiment*, as would have been necessary for the acquisition of but a moderate portion of chemical science.* Even the operations of calico printing, as practised by the people of India, and which, above all others, have been considered as the result of an improved state of chemistry, are, in many respects, highly inconvenient, and incumbered with useless parts, which a little chemical knowledge would have taught them to reject, as, indeed, they were rejected by the people of Europe, very soon after calico printing began to be practised here, though it began and was continued for some time with very little aid from chemical science. And, considering how far many of the operations of dyeing and calico printing have been carried towards perfection, unassisted by principles, we may say of this art, or, until very lately, might have said what Lord Bacon says of music, that "the practice has been well pursued, and in good variety, but the theory weakly; especially as to assigning the causes of the practice." Bacon's Works, by Mallet, vol. iii. p. 29.

But though the observations of many individuals, occupied with the means and operations of dyeing, through a long succession of ages in different countries, joined to very important *accidental* discoveries occurring from time to time, have produced great improvements in this art, with very little help from theory, we are not to infer that a knowledge of its true principles, and of the causes

* Pliny observes, that dyeing had never been considered as a liberal art; and he alleges this as an excuse for not giving a *rationale* of it. Lib. xxii. c. 2. But this was a mere excuse, because no degree of science then in the world could have enabled him to do so.

which operate in producing its various effects, will not prove useful in the highest degree; for, (as Mr. Henry has well observed,) " though long experience may establish a number of facts, yet, if the rationale of the manner by which they are produced be not understood, misapplications are liable to be made; similar practices are pursued where the cases differ essentially; and improvements are attempted at hazard, and often on false principles." And in confirmation of these truths, perhaps I cannot better conclude this Introduction, than by adding the following quotation from the History and Memoirs of the Royal Academy of Sciences at Paris, for the year 1761, *viz.*

" *La description des arts, faite avec une exactitude éclairée, depouillée de toutes les pratiques inutiles, que l'ignorance toujours mysterieuse y accumule sans cesse, et reduite* aux principes constans de la saine theorie, *est peutêtre, le moyen le plus propre à hâter leur perfection, et à rendre plus abondantes* ces sources de biens et de commodités, que l'être suprème a voulû que les hommes dûssent à leur travail, et à leur industrie."

PHILOSOPHY

OF

PERMANENT COLOURS.

EXPERIMENTAL RESEARCHES

CONCERNING THE

PHILOSOPHY

OF

PERMANENT COLOURS.

PART I.

CHAPTER I.

Of the Permanent Colours of Natural Bodies.

"Ceux qui exigent qu'on leur donne la raison d'un *effet general,* ne connoissent, ni "l'etendue de la nature, ni les limites de l'esprit humain."—M. DE BUFFON.

THE subject of this chapter was covered with darkness, until the immortal Newton threw light upon it, by *dissecting*, if I may so express myself, the *matter* of *light* itself. By his experiments we have been taught, that "the light of the sun consists of rays differently *refrangible;*" and that, when separated by the prism, in consequence of their different degrees of refrangibility, they afford all the various shades of colour, running gradually into each other, according to their particular degrees of refrangibility; the violet being most refract ed; the indigo next; then the blue, green, yellow, orange, and red, which last is, of all others, the least refracted; that the same rays also differ in degrees of reflexibility, according to their degrees of refrangibility.

That the proper colour of homogeneal light, depending on its particular degrees of refrangibility, cannot be

changed by reflections or refractions; and "If the sun's light consisted of but one sort of rays, there would be but one colour in the whole world," nor the possibility of producing any new colour by reflections and refractions; and, therefore, "that the variety of colours depends upon the composition of light."

That "colours, *in an object*, are nothing but a disposition to reflect this or that sort of rays, more copiously than the rest; *in the rays*, they are nothing but their dispositions to propagate this or that motion into the sensorium; and *in the sensorium*, they are sensations of those motions, under the *forms of colours*."

That "colours may be produced by composition, which shall be like to the colours of homogeneal light, as to the *appearance of colour*, but not as to the immutability of colour, and constitution of light; and those colours, by how much they are more compounded, by so much are they less full and intense; and by too much composition they may be diluted and weakened, till they cease, and the mixture becomes grey. There may be also colours produced by composition, which are not fully like any of the colours of homogeneal light." "For a mixture of homogeneal red and yellow, compounds an orange, like, in appearance of colour, to that orange, which, in the series of unmixed prismatic colours, lies between them; but the light of one orange is homogeneal as to the refrangibility, and that of the other is heterogeneal; and the colour of the one, if viewed through a prism, remains unchanged; that of the other is changed, and resolved into its component colours, red and yellow. And after the same manner, other neighbouring homogeneal colours may compound new colours, &c." And if to a colour so compounded, other colours be added in sufficient quantities, they will gradually overcome the first, and produce "white-

ness, or some other colour." "So if to the colour of any homogeneal light, the sun's white light, composed of all sorts of rays, be added, that colour will not vanish or change its species, but be diluted; and by adding more and more white, it will be diluted more and more, perpetually." "Lastly, if red and violet be mingled, there will be generated, according to their various proportions, various purples, such as are not like, in appearance, to the colour of any homogeneal light; and of these purples, mixed with yellow and blue, may be made other new colours." "That whiteness, and all grey colours between white and black, may be compounded of colours, and the whiteness of the sun's light, is compounded of all the primary colours mixed in due proportion." To illustrate this, he produced *whiteness*, first by a mixture or re-union of the several prismatic colours, and then, as he asserts, by mixtures of differently-coloured substances, in due proportions.*

Each particular colour being, therefore, a property of that particular sort of ray which produces the perception thereof, Sir Isaac Newton concludes, that the permanent colours of natural bodies arise from hence, that some of them "reflect some sorts of rays, others other sorts, more copiously than the rest. 'Minium reflects the least refrangible, or red making rays most copiously, and thence appears red. Violets reflect the most refrangible most copiously, and thence have their colour, and so of other bodies; and, "whilst bodies become coloured, by reflecting or transmitting this or that

* This last assertion appears incredible, unless the coloured substances were *all transparent*. A painter, I am confident, would never produce *white* from any or all of the several opaque colours, in whatever proportions they might be mixed; and the Dyer who should, in the usual ways, apply them to a piece of white cloth, would soon find it become *black*.

sort of rays more copiously than the rest, it is to be conceived that they stop and stifle in themselves the rays which they do not reflect."

Sir Isaac Newton's demonstrations and illustrations of this doctrine may be seen at large in the *first* Book of his Optics, to which I refer, without intending to propose any objection thereto. It may, indeed, be liable to several; but as these, even if well founded, would not affect my *ultimate* conclusions, I shall *thus far* adhere to the doctrine under consideration.

Sir Isaac Newton's second Book, however, contains matter to which I cannot assent. He begins it with "Observations concerning the reflections, refractions, and colours of thin transparent bodies;" and mentions, what had been observed by others, "that transparent substances, as glass, water, air, &c. when made very thin by being blown into bubbles, or otherwise formed into plates, do exhibit various colours, according to their various thinness; although at a greater thickness they appear very clear and colourless." And though he considers these colours as "of *a more difficult consideration*," yet as "they may conduce to farther discoveries for completing the theory of light, *especially as to the constitution of the parts of natural bodies, on which their colours or transparency depend*," he delivers his own observations on this subject: Of these, the principal was made, by taking "two object-glasses, the one a plano-convex, for a fourteen-foot telescope, and the other a large double convex, for one of about fifty foot; and upon this laying the other, with its plane side downwards, I pressed them slowly together, says he, to make the colours successively emerge in the middle of the circles, and then slowly lifted the upper glass from the lower, to make them successively vanish again in the same place. The colour which, by pressing the glasses

together, emerged last, in the middle of the other colours, would, upon its first appearance, look like a circle of a colour, almost uniform from the circumference to the centre; and by compressing the glasses still more, grow continually broader, until a new colour emerged in its centre, and thereby it became a ring, encompassing that new colour; and by compressing the glasses still more, the diameter of this ring would increase, and the breadth of its orbit, or perimeter, decrease, until another new colour emerged in the centre of the last; and so on, until a third, a fourth, a fifth, and other following new colours successively emerged there, and became rings, encompassing the innermost colour; the last of which was the black spot: And, on the contrary, by lifting up the upper glass from the lower, the diameter of the rings would decrease, and the breadth of their orbit increase, until their colours reached successively to the centre; and then, they being of a considerable breadth, I could more easily discern and distinguish their species than before." And these he found to be in succession from the black central spot as follows, viz. first, blue, white, yellow, and red; then in the next circuit or order, immediately encompassing these, were violet, blue, green, yellow, and red; in the third circuit or order, were purple, blue, green, yellow, and red; after this succeeded in the fourth circuit, green and red; then the fifth, of greenish blue and red; next, the sixth, of greenish blue and pale red; and lastly, the seventh, of greenish blue and reddish white: but the colours in the last three circuits he describes as having been very indistinct, and ending in perfect whiteness.

"By looking through the two object glasses," continues he, "I found that the interjacent air exhibited rings of colours, as well by transmitting light, as by reflecting it. The central spot was now *white*, and from

it the orders of the colours were yellowish red; black, violet, blue, white, yellow, red; violet, blue, green, yellow, red, &c. But these colours were very faint and dilute, unless when the light was trajected very obliquely through the glasses. Comparing the coloured rings made by reflexion, with those made by the transmission of light, I found," adds he, "that white was opposite to black, red to blue, yellow to violet, &c." And as rings of similar colours were observed in bubbles, "blown with water, first made tenacious by dissolving a little soap in it," Sir Isaac Newton endeavoured mathematically to ascertain the different comparative thicknesses of air, water, and glass, at which the several circuits or orders of colours appeared as before mentioned, which he has noted in a table prepared for that purpose, and from which this remarkable fact appears, that *similar colours* in the different orders *occur, and are repeated over and over again at very great diversities of thickness;* a circumstance which, in my humble opinion, *proves incontestably*, that though *thickness* might *be one*, it *could not be, as he supposes, the only cause of these repeated variations of colour.** It was, at that period, the fashion to ascribe *even chemical effects* to *mechanical causes:* alkalies were supposed to neutralize acids, as the blade of a sword is sheathed by its scabbard; and the most learned physician of his age, soon after, thought

* Sir Isaac Newton seems to have foreseen this objection to his hypothesis, and to have endeavoured to obviate it, by supposing the existence of what he denominated different *orders* of colours; in each of which it was conceived that the red, orange, yellow, &c. required for their production very different thicknesses from those which produced the same colours in the other orders: this, however, was but a supposition, improbable in itself, and repugnant to a multitude of facts, which will be mentioned in the course of this work.

it proper to write a *Mechanical Account of Poisons*. We are not, therefore, to wonder that Newton himself should have been misled on this subject, since the whole amount of chemical knowledge in his time, had he possessed it, would, like an *ignis fatuus*, have only served to light him astray; as in truth it seems, in some degree, to have done; for, after stating as a proposition, that "the transparent parts of bodies, according to their *several sizes*, reflect rays of one colour, and transmit those of another, on the same grounds that thin plates, or bubbles, do reflect those rays," he goes on to mention, "that, by mixing divers liquors, very odd and remarkable productions, and changes of colours, may be effected; of which no cause can be more obvious and rational, than that the saline corpuscles of one liquor, do variously act upon, and unite with, the tinging corpuscles of another, *so as to make them swell or shrink* (whereby not only their bulk, but their density also, may be changed), or to divide them into smaller corpuscles (whereby a coloured liquor may become transparent), or to make many of them associate into one cluster, whereby two transparent liquors may compose a coloured one:" and laying it down as a proposition, that "the *bigness* of the component parts of natural bodies, may be conjectured by their colours," he endeavours, among other things, to explain why the syrup of violets, "by acid liquors, turns red, and, by urinous and alkalizate, turns green;" and for this purpose, he supposes, that "it is the nature of acids to dissolve or attenuate, and of alkalies to precipitate or incrassate;" a supposition, which, as acids and alkalies are *chemical agents*,* is not true of either of them, in the sense in

* When acids "dissolve or attenuate," it is by combining and forming a new compound with the matter so dissolved or attenuat-

which Sir Isaac Newton appears to have understood it; though, in another sense, it is partly true and partly false of both; since both are capable of dissolving a great variety of substances, and when a substance is dissolved by either, it will most commonly be decomposed and precipitated by the other: but certainly the effect of coagulating, or *incrassating*, which he ascribes to alkalies, is much more frequently produced by acids; though nothing like it is produced in any of the changes of colour, which they occasion to the syrup of violets. It must be also observed, that Sir Isaac Newton has himself admitted, that what he calls "fat, sulphureous, unctuous bodies," possess refractive powers "two or three times greater, in respect of their *densities*, than the refractive powers of other substances, in respect of their's;" an admission, which seems incompatible with the conclusion which he almost immediately after draws, "that nothing more is requisite for producing all the colours of natural bodies, than the several sizes and densities of their parts."*

ed; and when alkalies "precipitate or incrassate," they always produce decompositions, and new compounds, which are totally foreign to those mechanical effects by which Sir Isaac Newton intended to explain the changes of colour in question.

* Since my objections to this part of Sir Isaac Newton's doctrine were published, Dr. Young, in the first volume of his Lectures on Natural Philosophy, p. 469, has delivered the following observations respecting the Newtonian theory of the colours of natural bodies, viz.

"Sir Isaac Newton supposes the colours of natural bodies in general, to be similar to these colours of their plates, and to be governed by the magnitude of their particles. If this opinion were universally true, we might always separate the colours of natural bodies by refraction into a number of different portions, with dark spaces intervening; for every part of a thin plate, which exhibits the appearance of colour, affords such a divided spectrum, when viewed through a prism. There are accordingly many natural co-

In thus extending and applying his conclusions, respecting the *transient* colours of pellucid plates and bubbles, to the *permanent colours of all natural bodies*, Sir Isaac Newton appears to have been influenced solely by *analogy;* he having made no experiment, or observation, which would justify this extension. But in the year 1765, Mr. Edward Hussey Delaval, F. R. S. endeavoured to supply this omission, by communicating some experiments, and observations, on the agreement between the specific gravities of the several metals, and their colours, when united to glass, as well as of their other preparations, in a letter to the Earl of Morton, then president of the Royal Society: a communication for which the Society bestowed on him the annual gold medal provided by Sir Godfrey Copley. And though Mr. Delaval, in this communication, "treats of the difference of *density*, and the *colours* produced by that cause," he, notwithstanding, considers these as connected with "the colours arising from a difference of the size of the colouring particles;" since, "by separating the particles of a coloured substance, they are removed to a greater distance from each other, so as to occupy more space," and, therefore, the substance so affected, "must undergo *a diminution of its specific gravity*, *at the same* time that the size of its particles is

lours in which such a separation may be observed; one of the most remarkable of them is that of blue glass, probably coloured with cobalt, which becomes divided into seven distinct portions. It seems, however, impossible to suppose the production of natural colours perfectly identical with that of the colours of thin plates, on account of the known minuteness of the particles of colouring bodies, unless the refractive density of their particles be at least 20 or 30 times as great as that of glass or water; which is indeed not at all improbable with respect to the ultimate atoms of bodies, but difficult to believe with respect to any of their arrangements constituting the diversities of material substances."

lessened." And as Sir Isaac Newton had inferred, that the refractive and reflective powers of bodies, were nearly proportional to their densities, and that the least refrangible rays, require the greatest power to reflect them, Mr. Delaval conceived, " that denser substances ought, by their greater reflective power, in like circumstances, to reflect the less refrangible rays; and that substances of less density, should reflect rays proportionably more refrangible, and thereby appear of several colours, in the order of their density." And, in support of this opinion, he undertook to " give instances of natural bodies, which differ from each other in density, though circumstanced alike in other respects;" and also differ " in colour, in the same order as they do in density; the densest being red, the next in density orange, yellow, &c.

" In such an inquiry," says he, " metallic bodies seem to demand our first and principal attention, as their specific gravities have been ascertained, by well-known and repeated experiments." Mr. Delaval, however, must doubtless have perceived, that metals, in their pure simple forms, could not suit his purpose of supporting and extending the doctrine of Sir Isaac Newton, in this respect; since platina, which is much the heaviest of all metals, and of all known substances, instead of being the *most red*, as upon this hypothesis it ought to have been, is white, like tin, the lightest of metals; and gold, the heaviest of metals after platina, is much farther removed from the red colour than copper, which is so much lighter. And this is more remarkably the case of quicksilver, lead, &c. To obviate so formidable a difficulty, he thought it expedient to premise, that, " as the *inflammable matter* in the entire metals, acts strongly on the rays of light, it is necessary to calcine, or divide them into extremely minute particles, in

order to examine separately the action of the calx, or *fixed* matter, on the rays of light." But here, at the very threshold, Mr. Delaval is forced to suppose the presence of what he calls inflammable matter *acting strongly on the rays of light*, and thus producing or changing colours, by properties very different from those of density, and size or thickness of particles. I might here deny, as, in truth, I am very far from believing, the existence of any such matter in metals, which, according to the new and prevailing chemical doctrine, are simple substances, uncombined with any such matter as is here supposed. Admitting, however, for the sake of argument, that phlogiston, or inflammable matter, does exist in metals; it must be recollected, that their calcination is not a mere abstraction thereof; since there is no fact in chemistry better ascertained, than that every metal in its calcination unites with a considerable portion of vital air, or its basis, the oxygene* of the modern chemists, and which (only by va-

* By oxygene is meant that substance which, combined with and rendered elastic by heat, or by heat and light, constitutes vital air; or what Dr. Priestley terms dephlogisticated air (first discovered by him in August, 1744), the only fluid suited for respiration; the *pabulum vitæ*, without which the more perfect animals cannot live, even for a few minutes. But as the stimulant or exhilarating effects of this (vital) air would excite, and wear out, the powers of life too much and too rapidly, if it were inspired without mixture, the wise Author of Nature has presented it to us diluted with nearly four times as much of a different air not respirable by itself, and which is now denominated *azote*, or nitrogene. These two airs, with a very small portion of carbonic acid gas, or fixed air, and some accidental or extraneous matters, compose our common atmospheric air. The oxygene, combined with nitrogene, constitutes, according to their different proportions, either the nitrous or nitric acid; the same oxygene united to sulphur by combustion, produces either sulphureous or sulphuric (vitriolic) acid; and, with other bases, it seems to produce most of the other acids. With pure

riations of proportion) is capable of producing, with particular metals, (and with other substances), all the possible variations of colour. Of this, however, Mr. Delaval takes no account: indeed, when treating of the colours of mercury, he expressly says, "I have not entered into the consideration of the air, which unites with mercurial colours during their exposure to fire; because it does not relate to *the greater or less division of their particles*, which is the immediate subject of my inquiry." So that, by his own statement, he has overlooked (because it did not suit his hypothesis) *the only thing worthy of notice on this subject;* since the oxides or calces of mercury, and, indeed, of all other metals, indisputably receive their various colours only by additions, greater or smaller, of that air which he professes to have disregarded; and which, as he declares, has no relation to the greater or lesser division of their particles; and we must therefore conclude, that the various colours assumed by these calces, under the circumstances in question, do not result from any such division.

But though Mr. Delaval inculcates the necessity of calcining metals, "in order to examine separately the action of their calces or fixed matter, on the rays of light," he does not adduce the colours which they assume when so calcined, as any evidence of the truth of his hypothesis; and, indeed, he might have perceived them to be absolutely incompatible with it, since the same oxide, by different degrees of calcination, exhibits very great diversities of colour. But in order to obtain from several of the metals such colours as *suited* his

charcoal (carbone) it produces carbonic acid (or fixed air), and with inflammable air (hydrogene) it produces water. This explanation may be useful to readers not acquainted with the modern chemistry.

purpose, he continued to melt them with what he was pleased to think "a quantity of the purest glass," and as they, when more or less calcined, and melted or united with a greater or less portion of glass, are capable each of giving several, and some of giving all the colours, it could not be difficult for him to find out, and assign to each metal, as its proper colour, that which it ought to have, upon his supposition that the colours of metals depended on their respective densities. Thus, for example, iron highly calcined, or combined with a large portion of the basis of vital air, (oxygene), gives a red colour to melted glass; and if the glass be continued in fusion, the (oxygene) will by degrees be separated, and in proportion to its separation, the colour of the glass will change to orange, yellow, green, blue, and white. And as blue is the colour which suits Mr. Delaval's purpose, he selects and assigns it as the proper colour of iron, and the degree of heat producing it, as the proper one for manifesting those which suits him to consider as the true colours of metals; though in fact he took no means to ascertain what this degree of heat really was; and the effect, or blue colour, would require very different degrees, according to the greater or lesser degree of calcination which the iron had previously undergone, or, in other words, according to the quantity of oxygene previously combined with it.

Where every thing is in this way assumed or supposed at pleasure, not only without evidence or probability, but often against both, it must have been easy for Mr. Delaval to give some plausibility to this fallacious hypothesis, though it is absolutely incompatible with a multitude of facts.

Mr. Delaval has quoted, from Glauber's Prosperity of Germany (translated by Packe, 1689), some curious observations respecting the various colours produced

by manganese; and he adds, as from his own knowledge, that "amongst the mineral substances, none affords a greater variety of bright colours, especially when it is fused with nitre, or a fixed alkali;" of these he instances a yellow, produced by dissolving manganese in a weak spirit, together with a green, blue, purple, and red, produced by water poured on it; in the first instance cold, and in the others warm, then warmer, hot, and boiling; all which colours he ascribes to different degrees of solution, or attenuation, of the particles of manganese. But in truth this and other metallic calces or oxides, had he properly attended to their various changes of colour, might have shown him both the fallacy of his own hypothesis, and the road to a better. Manganese is the oxide or calx of a metal which has so strong an attraction for the basis of vital air, that one of the most excellent of chemists, Berthollet, says, we may safely consider the whole of what exists in nature to be as in a state of oxidation, or combination with oxygene: when saturated therewith, I mean with the basis of vital air, it is black; and if it be diluted or diffused in melted glass, it becomes purple, or red; and as the vital air diminishes by burning with the coaly impurities, (which it is employed to destroy), in glass, it gradually loses its power of producing colours, and leaves the glass colourless; though its colours may be restored by nitre, or any thing affording pure air. The different solutions of manganese, mentioned by Glauber, and others, undergo their various changes of colour, in consequence of a gradual separation or diminution of their oxygene; and that this is what manganese possesses, and what it loses, in these operations, is well known to all who are acquainted with the later chemical discoveries. I have already noticed the various colours assumed by the oxides or calces of iron, when com-

bined with different portions of the same air, or its basis, the oxygene, which are indeed so many and various, that I remember having been told by the late Mr. Wedgwood, that all the diversified colours applied to his pottery, were produced by the oxides of this single metal; which must have been all of very nearly the same specific gravity, and they were besides, in these cases, combined or melted with glass, the substance which Mr. Delaval thought proper to choose, as being of all others the best, for exhibiting what he was pleased to think the true colours of metals. In like manner the oxides or calces of mercury, lead, copper, &c. assume each a variety of colours, by combinations with different portions of oxygene, without any thing like a correspondent variation of density, or of specific gravity in any of them. Of this Mr. Delaval appears to have been sensible, at least in the instance of lead, and he endeavours to obviate the evidence which it affords against his theory, by ascribing the various colours of that metal to its "imperfection," which he is pleased to *suppose*, without any, and against every, kind of proof and probability: and then he proceeds to say, "it is probable that, during the calcination, lead receives a small portion of *phlogiston*, as well as of air; for the affinity between the earth of this metal and inflammable matter is very great, as appears from the readiness with which its solutions and calces unite with phlogistic vapours." "The effect of such an union," he adds, "must probably be a change of colour from orange to red; for Sir Isaac Newton has shown, that bodies reflect more strongly in proportion as they possess more phlogiston, and that the less refrangible colours require greater power to reflect them." Here we have another gratuitous and strange supposition of an accession or combination of phlogiston with lead in calcination: I

say strange, because those of the adherents of phlogiston who yet continue to believe its existence in metals, have constantly supposed that, in calcination, while they received air, they *lost*, *instead of gaining*, *inflammable matter*. But were this extravagant supposition to be admitted as a cause of the changes of colour in metals, how can it be reconciled to any hypothesis which makes their colours depend on their respective densities? Indeed, if the effects which Sir Isaac Newton supposes phlogiston to produce on colours were real, and if phlogiston existed in them, as he and Mr. Delaval imagined, it would be difficult to conceive why all metals are not red, or more inclined to redness, than their calces or oxides. But enough, perhaps too much, has been said, to refute Mr. Delaval's hypothesis, so far as it relates to the colours of metals. Unfortunately, however, for my readers, as well as for myself, he has thought proper, in a larger work,* published some time since, to extend the same hypothesis to the colours of animal and vegetable substances; and has endeavoured to confirm and illustrate Sir Isaac Newton's ideas on this subject, by a variety of experiments, which are represented as instances of changes of colour produced in these substances, by an increase or diminution in the sizes of their particles: I am, therefore, compelled reluctantly to extend my own observations a little farther on this subject; and I must begin by complaining of a continuance of *gratuitous* and *fallacious suppositions*, similar to those which I have before had occasion to notice; for when, in operating upon, or with different matters, he professes either to increase or diminish the sizes of their particles, and *to do nothing more*, (to show that

* Experimental Enquiry into the Cause of the Permanent Colours of Opake Bodies. 4to.

the changes of colour produced in them, accord with the thicknesses stated in the table of Sir Isaac Newton,) instead of choosing and employing *mechanical* means, which alone are suited to produce these, and *only these effects*, he has recourse to mere *chemical* agents, whose action in the ways which he supposes, must have been always doubtful at least, though their powers of producing other, and very different effects from any supposed by him, is most certain. Mr. Delaval, however, adopting Sir Isaac Newton's supposition, that acids always attenuate, and alkalies always incrassate, prepared what he considered as a dissolving or attenuating liquor; which "consisted of water, with about an eightieth part of *aqua fortis:* and when he wanted to lessen the dissolving force of this liquor, instead of weakening it by the addition of water (which would certainly have been the most obvious and unexceptionable expedient), he chose to do it, as he says, by adding "a small quantity of a solution of potash, or some other alkaline liquor;" and thereby produced a new composition, the effects of which must, in many cases, prove different from those of a mere diminution of the supposed dissolving power of the former liquor. And on the other hand, when he wanted to increase the force of his acid liquor, instead of doing it by a farther addition of aqua fortis (obviously the most proper expedient), he recurs to an addition of *oil of vitriol;* an acid possessing very different properties, and producing very different effects, on a great variety of substances, and particularly on colouring matters; of which I could allege hundreds of instances, but shall content myself with only mentioning, that the strongest and most concentrated oil of vitriol (used to dissolve indigo for dyeing the Saxon blue, &c.) does not destroy, or even weaken, its blue colour, though a diluted nitric acid, or aqua fortis, will wholly

destroy it, and convert the indigo to a dirty brown mass, of no use whatever.

Having thus assumed, that acids attenuate, and do nothing but attenuate, the particles of colouring matter; that alkalies incrassate, and doing nothing but incrassate, the same particles; that by adding an alkali to his mixture of aqua fortis and water, he weakens, and only weakens, its attenuating force on one hand; and that on the other he increases, and only increases it, by an addition of vitriolic acid; he next provides himself with so much of Sir Isaac Newton's table before mentioned as suits his purpose, by transcribing the different colours of the three first orders, and the different thicknesses of air, water, and glass, supposed to produce each of these colours, one after the other; and thus *equipped*, he proceeds to make experiments upon red infusions, of certain vegetables, and generally finds, that with his acid liquor, the colour continues *red;* that, with the addition of oil of vitriol, to attenuate farther, (as he supposes) it becomes yellow; and that if, instead of oil of vitriol, he adds an alkali, to *incrassate*, it becomes a purple. Now it so happens, that though all the other colours are repeated in more than one order, purple is marked but once in Sir Isaac Newton's table, and then it is placed as the first colour of what he terms the third order; and if the red and yellow, from which the purple in question had proceeded, were supposed to be of the same order (as might be expected), then the production of this purple ought, upon Mr. Delaval's theory, to result not from incrassation, but from attenuation; since the particles of it are stated to be nearly one third less in size, than the particles of the red, and nearly one fourth smaller than those of the yellow of the same order: but such is the happy arrangement of this table, and of the several orders of colours, that, by supposing

the red in this instance to be the red of the second order, he finds a purple below it in the third, with *only one intervening colour*, and a yellow at *the same distance above;* and by these *leaps*, he reconciles the appearances to the theory. Indeed, as the second, or middle order in the table, contains all the different colours, and as, excepting one, they are all repeated in the first order, which is *above;* and also in the third, which is *below;* hardly any change of colour can happen, which may not be made to accord with Mr. Delaval's hypothesis, he being always allowed to suppose each original or primitive colour to belong to that order which may be most convenient for his purpose; though, in truth, the very admission of different orders or repetitions of the same colours, produced repeatedly by and at *different* thicknesses, or sizes, either of particles or plates of matter, is of itself a proof (as I have before observed) that such colours do not depend on any particular thickness of plates or size of particles.*

* When Mr. Delaval, on every occasion, allots each particular colour to some one order, exclusively of the rest, it would seem reasonable to expect, that he should justify this allotment by something besides his own convenience, and particularly that he should prove that the red, for instance, which he places in the second order, exceeds that of the first order, in the density and size of its particles, exactly in the same proportion as $18\frac{1}{3}$ exceeds 9; and that the red which he places in the third order, exceeds that of the second exactly in the proportion of 29 to $18\frac{1}{3}$: and that the other colours of the several orders, differ from each other likewise, according to the proportions stated to be *necessary* for their production, in the table which he has adopted from Sir Isaac Newton. Before this division of colours into orders, and the hypothesis connected with it, can be admitted to have any other than an imaginary foundation, it ought to be proved, that all the known reds, differ from each other in respect to the densities and sizes of their particles, *exactly according to the before-mentioned proportions;* and so of the oranges, yellows, &c. since, in every case, the slightest deviation

I am far from thinking that Mr. Delaval has always chosen the matters, most proper for fair experiments, or that the experiments themselves, even on his own principles, were well calculated to ascertain the truth. But such as they are, I can readily point out several, which, on his own improbable, or rather impossible supposition, of mechanical attenuation or incrassation, and nothing else, by chemical agents, cannot be reconciled to his theory, even by the assistance of Sir Isaac Newton's convenient table. The green leaves of the anil (indigofera) and glastrum, he says "being long steeped in water, their parts are *dissolved* into a blue substance, which is indigo and woad." Now the truth is, that the blue arising from these vegetables is not the result of any *dissolution*, but of an absorption of pure air, during the fermentation which they undergo; and this colour does not manifest itself, until there is a beginning *aggregation* and *concretion* of its matter, into *larger* particles, which becoming *denser*, as well as *larger*, sink down to the bottom, leaving the water nearly colourless. So that here the change from green to *blue*, is manifestly accompanied with an increase, both in the size and density of the coloured particles, which is absolutely incompatible with Mr. Delaval's hypothesis; since, according to the table in question, every change of colour from green to blue is the effect of a *diminution*, not an *increase*, in the size and density of its particles. When the indigo itself (formed into dry masses) is to be dissolved for dyeing, by the combined

from the thickness or size of particles, stated as essential to the production of a particular colour, ought to occasion the appearance of that colour, which is next in the series above or below. But nothing like this is any where attempted, nor is there any thing accessible to human observation, which could in any degree justify the attempt.

action of *caustic* alkalies, and of particular chemical attractions, or vegetable ferments, the solution, though manifestly attended with a division or diminution of the coloured particles (as well as a loss of the air absorbed during the first process) becomes green, *contrary* to the table and hypothesis in question; and in this state, it is applied by the dyers to wool, and other substances, to be dyed; and these, when first taken out and exposed to the air, appear green; but by absorbing, and uniting with a portion of oxygene, they immediately become blue, and in doing so, the divided particles again concrete into larger ones, as must be evident, among other proofs, from this, that the surface of the indigo liquor, on which the air has an immediate action, is from that cause always blue; and if we skim off this blue matter, (which is nothing but indigo revived) it will be found impossible to make it enter the pores of any substance, so as to dye a permanent colour therewith; because the particles having regained their proper portion of pure air, or its basis, are no longer sufficiently divided and dissolved for that purpose; so that in all these cases, the matter of indigo becomes more dense, and its particles larger, in passing from green, to the more refrangible colour, blue; and the contrary, in passing from blue to the less refrangible colour, green. And this is also the case, when the infusions of rhubarb, turmeric, &c. are made "to descend (as he expresses it) from yellow to orange and red," "by the addition of an alkali," which, whatever he may imagine to the contrary, *dissolves* these colouring matters more powerfully than any acid. Similar objections occur, in opposition to the instances which Mr Delaval alleges, respecting "the changes of colour which animal substances undergo." Among these, *e. g.* he observes, that cow's milk, boiled up with an alkali, changes from white to yellow, orange, and red; and, as usual, he gratuitously supposes, that, in produc-

ing these changes, it acts by *incrassating*, or coagulating the milk; though if, contrary to all probability, alkalies were able to do this, we have no reason to conclude that such coagulation would render the milk either yellow, orange, or red, because no such colours appear when it really is coagulated by acids, &c. as in the making of curds and cheese. But surely it cannot be necessary for me, seriously to combat such chimeras any longer. The common sense and experience of mankind, if fairly consulted, will condemn and revolt at the idea of making the colours of bodies depend on their weight, or the sizes of their particles; for it certainly never has been observed, that the heaviest substances were red, or the lightest violet-coloured, or that bodies equally heavy were all of the same colour. Different parcels of indigo, for instance, vary extremely as to specific gravity, without any variation of colour; a fact which is not only at variance with Mr. Delaval's hypothesis, but which renders it easy to find samples of indigo, of exactly the same specific gravity as the colouring matter of cochineal (exhibited in what is called *carmine*,) which of all colours is the farthest removed from that of indigo: and if Mr. Delaval should allege, that, though agreeing in weight, they differ as to the sizes of their respective particles, let him correct this difference by the only means suited to do it, without doing more; I mean by simple mechanical division, or grinding. Let this be employed upon either of the substances in question, whose particles he may suppose too large, as long as he shall think proper, and let us then see whether he can thereby render the colour of indigo red, or that of cochineal blue or violet.

Should what I have said on this subject prove insufficient to convince any one of my readers, I only beg that he will follow me, with a mind open to conviction, through the various instances, which, for other pur-

poses, I shall have occasion to state hereafter, of colours produced, or changed by means, and in ways, that are wholly irreconcileable to the theory in question, and I persuade myself that his doubts and difficulties will be effectually removed, so far as they may relate to the truth or fallacy of Mr. Delaval's hypothesis, of which I mean hereafter to be silent, because I dislike even the appearance of contention; nor would I have so long detained my readers on this subject, but from a conviction of the truth of what I have written, and of the expediency of refuting an hypothesis, incompatible with a considerable part of what I am about to offer to the public; an hypothesis which the name and authority of Sir Isaac Newton had pre-eminently sanctioned; and which the learning and talents of Mr. Delaval had rendered so plausible, that it is, I believe, generally considered as true, in this and other countries.*

Having shown, that the permanent colours of different objects do not arise from their densities, or the sizes of their particles, it becomes me to state such facts and observations, as seem best suited to throw light upon this obscure and interesting subject.

Sir Isaac Newton having found that inflammable substances, possessed greater refractive powers than others, in proportion to their densities, says, in his second Book of Optics, that "it seems rational to attribute the refractive power of all bodies, chiefly, if not wholly, to the sulphureous parts with which they abound; for, adds he, it is probable that all bodies abound more or less with sulphurs;" a term by which he intended to distinguish inflammable matters generally. And this great man having also concluded, that the permanent colours of natural bodies, were analogous to the colours

* Such *was* the fact in 1794, when this was first published.

produced by the refractions of thin, colourless, transparent plates, &c. chemists were generally induced to make all colour depend on the principle of inflammability or phlogiston, which was supposed to exist in all metals, and many other substances; and where the total want of inflammability was manifest, they *confounded this*, with the *matter* of heat and of light; to which they ascribed the power of *phlogisticating* other substances, and of thereby producing or changing their colours: a species of confusion suited only to cover and perpetuate ignorance; since every single colour is found to belong both to combustible and incombustible substances, and to neither exclusively. The *combustible* diamond, which Sir Isaac Newton conjectured to be "*an unctuous substance* coagulated," is found to be of almost all the different colours; whilst other gems, though of similar colours, are all *incombustible*. Combustible indigo, and incombustible smalt, are both blue; combustible vermilion and incombustible minium are both red; combustible gamboge is yellow, and so are certain incombustible oxides of lead, iron, and mercury. But since the existence of phlogiston in metals, &c. has been denied by the pneumatic chemists, they have in most cases, attributed the origin and changes of colours, to the application or combination of different airs or gases, and particularly oxygene in different proportions; and it has been supposed that these gases possessed considerable *refractive* powers, and were *thereby* enabled to produce effects on colours, like those which the followers of Stahl had imputed to phlogiston: and M. Berthollet, in his recent work on the Elements of Dyeing, intimates, that "many important observations still remain for those who would follow the steps of that great man, (Sir Isaac Newton), and compare the *refracting* powers of the different gases, and other sub-

stances, the constituent principles of which are now known."*

Though it be true that the prism, and other transparent colourless substances, in different forms, show us the different colours of the several rays of light, by *separating* them from each other, in consequence of their greater or lesser refrangibility, or disposition to be "turned out of their way, in passing out of one transparent body or medium into another," (which may depend upon differences in their sizes, densities, or velocities,) yet the *permanent* colours of different bodies, or substances, *are not*, as I believe, *produced by mere re-*

* Ten years after my first edition of this volume was published, M. Berthollet (assisted by his son, lately deceased, and too soon for the interests of science) favoured the public with an improved edition of the Elemens de Teinture, in which (at page 33, of the first volume) he intimates, that it was his intention, by the words just quoted, to express some doubt of the correctness of this part of Sir Isaac Newton's doctrine; and he adds, "depuis lors Bancroft lui a opposé un grand nombre de faits. Nous nous servirons de ses differentes observations, dans la discussion que nous n'allons entreprendre, que dans la vue d'appeler sur cet objet interessant, l'attention de ceux qui peuvent suivre les traces de *Newton*." He then proceeds through nearly twenty pages to repeat the facts and arguments which I had employed on this subject, and to adduce other facts and arguments in their support, from all which he concludes, nearly as I had done, "qu'il ne faut point confondre les couleurs fugitives qui sont produites par la reflexion des lames, et qui suivent les loix determinées par Newton, avec les couleurs qui se conservent malgré les changemens de densité et d'épaisseur. Celles-ci nous paraissent tenir a des propriétés, ou l'affinité particuliere pour les différents rayons de la lumiere, a une influence qui resiste a celle des dimensions et de la densité; si nous examinons les faits, nous apercevons que l'oxigène condensé exerce un grand pouvoir dans cette espéce d'affinité: une proportion un peu plus on un peu moins grande, qui affecte d'une maniere insensible la pesanteur spécifique des oxides métalliques, y produit de grands changements de couleurs," &c.

fraction, and Sir Isaac Newton must have been misled by analogy when he extended his discoveries and conclusions respecting the transient colours resulting from the refractions of light, by pellucid colourless substances, to the permanent colours of various kinds of matter; since the latter evidently depend on other properties, which determine, or occasion the reflection or transmission of some particular sort or sorts of rays, and an absorption or disappearance of the rest; and these I conceive to be certain *affinities*, or *elective attractions*, existing in or between the differently coloured matters and the particular sorts or rays of light so absorbed or made *latent;* and of which many instances and proofs will, I think, be found in the subsequent parts of this work.

Next after the diamond and amber, we find that spirit of turpentine, linseed oil, olive oil, camphor and alcohol, or rectified spirit of wine, possess greater refracting powers, in proportion to their respective densities, than any of the other substances contained in Sir Isaac Newton's table, and yet they are all *permanently destitute of colour;* a fact which does not seem to indicate any connexion between the refractive power of a substance and its natural *permanent colour*. Nothing seems to act so powerfully and extensively in producing and changing those affinities, or elective attractions, from which the permanent colours of different substances arise, as pure vital air, or its basis, the oxygene; which, indeed, seems to owe its elastic, or aërial form, to a portion of light as well as heat. Scheele demonstrated that gold, silver, &c. were revived from their oxides by the contact of light; and M. Berthollet has proved, that, in producing this effect, the light occasions a separation of oxygene, in the form of pure vital air. Light also separates oxy-

gene from various other substances, to which it would otherwise remain united, under great degrees of heat.

We are at this time well acquainted with the constituent parts of the acid of nitre: it undeniably consists of nitrogene or azote, rendered acid by its combination with a certain portion of oxygene, or the basis of vital air. When these are combined in a certain proportion, the acid or compound is colourless, as we see it in aqua fortis, or nitric acid: but if this colourless acid, in a transparent glass vessel, *partly filled*, be exposed to the rays of the sun, or the light of a fire, an alteration will take place in the proportion of its ingredients; since the light will combine with a part of the oxygene, and cause it to become elastic and fly off, and the nitrogene will consequently predominate in the remainder; which, becoming *nitrous acid*, merely in consequence of this predominance, will assume first a yellow, then an orange, and afterwards a high vivid aurora, and even a red colour, intensely affecting the sight. But if the glass vessel containing the colourless nitric acid, were *completely filled* with it, and closely stopped, no such change of colour would take place by any degree of exposure to the sun's rays or other light; because, in this case, there would be no sufficient space or room to allow of a separation and escape of the oxygene. When nitrous acid has been made to assume the colours before mentioned, if the glass vessel containing it be hermetically sealed and kept for some time in the dark, the oxygene by losing its light, will lose its elasticity; and being again re-absorbed by the nitrous acid, the latter will become colourless, as before. Mr. Keir mentions an orange-coloured nitrous acid, which, by long keeping, became green, and afterwards of a deep blue; and Bergman says, that if, to a concentrated red nitrous acid, one-fourth part of the quantity or measure of water be

added, the colour will be changed to a fine green; and to a blue, by the addition of an equal measure of water; and that double its quantity of water will destroy the colour. Here then we have an example of all the various colours produced by the two species of air which almost exclusively compose our atmosphere, when deprived of their elasticity, and mixed in particular proportions with more or less dilution by water.

In the same manner, colourless nitric acid, when applied to wool, silk, fur, or the skins of animals, their nails, horns, &c., renders them all not only yellow, but orange, and even aurora-coloured. M. Berthollet thinks, these changes are produced by a kind of combustion; but I am persuaded they are the result of a combination of the oxygene with the nitrogene, which he has proved to be a constituent part of all animal substances; these changes being exactly similar both in their nature and origin, to the changes of colour produced as before mentioned in the nitrous acid. Were these colours the effect of combustion, why are they not likewise produced in the same manner upon linens, and cottons, which are without nitrogene, but contain a great portion of the basis of charcoal, and ought therefore to be more liable to be acted upon in the way of combustion, than animal substances?

Long before the properties of the several kinds of air were known, many changes of colour had been noticed as produced by the application or action of light; and indeed its effects are so remarkable, in many cases, that no one can doubt of its powerful agency in these and other respects.* The principal thing to be ascertained

* Light not only contributes most efficaciously to the production of some colours and the destruction of others, but it greatly weakens the texture and fibres of silk, linen, cotton, &c. when they are long

on this point is, whether the colours which accompany, or require the application of light, result in each particular instance directly from a combination of it with the coloured substance, or indirectly from its particular action in occasioning either a separation of oxygene, or a combination thereof with the coloured matter? M. Sennebier attributes the effects of light upon colouring matters, to a *direct* combination of the former, with the latter;* but of this, though it may be true, he has not alleged any sufficient evidence, so far as I am capable of judging; and there are many facts which prove that the sun's beams, in some cases, favour the action of oxygene upon, and its combination with, colouring matters; whilst in *other cases*, it manifestly produces *opposite* effects upon these matters, by decomposing or separating some of their constituent parts, and especially the oxygene previously united to them: and probably these are the only ways in which it affects colours; it being doubtful whether light ever unites itself so *permanently* to any matter as it must do, to produce the *lasting* colours given by dyeing.

From the experiments of Beccari, Meyer, Schulz, Scheele, and Sennebier, it appears that muriate of silver (horned silver), which is nearly of a pearl white, changes to a violet colour, and from thence to a black, in the space of a very few minutes, when exposed to the sun's rays in a transparent glass; and this change Sennebier ascribes solely to the action of light; since, as he maintains, the muriate of silver will invariably retain its whiteness, though exposed either to heat or cold, and in a moist or a dry air, or in *vacuo*, if secured from the

exposed to the direct action of the solar rays; as may be seen in window curtains, blinds, &c. which, from that cause only, will, in a few years, tear as readily as brown paper.

* See "Mem. Physico-Chimiques sur l'Influence de la Lumiere Solaire," &c. tom. ii. and iii.

accession of light, and of what he calls phlogistic vapours (probably sulphuretted hydrogenous gas), and that it loses its whiteness only by the application of light, and then only in proportion to its quantity or intensity; so that when the sun's rays are copiously applied by a lens, the muriate of silver is rendered violet coloured in a single second. By covering the muriate of silver with four thicknesses of white paper, its whiteness was preserved; one, two, and three thicknesses retarded, but did not prevent its finally becoming violet and black. Mr. Sennebier found that the different rays of light, under the same circumstances, coloured the muriate of silver with different degrees of celerity; *i. e.* the *violet* rays in 15 seconds, the purple in 23 seconds, the blue in 29, the green in 37, the yellow in 5 minutes and 30 seconds, the *orange in* 12 *minutes,* and the *red in* 20; but the rays of the three last colours would not, as he relates, produce such a dark violet colour in any length of time, as was thus quickly produced by the more refrangible rays.* I have also witnessed some of these, and other changes of colour, taking place in muriated or horned silver, which manifestly result from an incipient reduction or revival of the metal, and with it a production of the dark colours which silver always manifests in that state; and in confirmation of this, I need only mention what I have several times observed, that though muriated silver, placed at the bottom of a colourless glass vessel, nearly filled with water, was made violet coloured in about two minutes, by the weak light of a room, having a single window only, and

* These facts which formerly appeared unaccountable and extraordinary, may now be readily explained by those which Mr. Herschell subsequently discovered and published (i. e. in 1800) respecting the composition of the sun's beams, and the very different powers of their several constituent rays.

in a cloudy day; yet a direct application of the sun's rays for many days produced no change of colour, when the muriated silver was covered with muriatic acid instead of water; a revival of the silver not taking place, whilst so much uncombined muriatic acid remained in contact with it.

A solution of silver in the nitric acid likewise changes colour by the action of light, and becomes black *thereby*, as well as by the application of inflammable substances, of calcareous earth, and every thing which separates a sufficient portion of the oxygene. It also gives the skin a black colour, which cannot be effaced, but by a removal or change of the skin itself: it tinges the hair, nails, and other animal substances, in like manner, because they occasion a separation of so much of the oxygene as is necessary for that purpose.

Mercury dissolved in nitric acid, being washed with water, affords a yellow oxide, which, when exposed to the light in a transparent colourless glass vessel, will become black on the side to which the light is applied, even where the vessel is filled with water; because the light extricates a part of the oxygene; this yellow oxide being a preparation of mercury, with but a very small proportion of acid. The red precipitate, and several other preparations of mercury, have their colours changed even under water, by similar means. The white or colourless solution of mercury, by the nitric acid, when applied to animal and inflammable substances, tinges them purple and black, in the same way, and from the same cause, as they are tinged by the solution of silver. Similar effects happen with the solution and oxide of bismuth, which last is therefore used to blacken hair when mixed with pomatum. Almost all the other metals afford instances of changes of colour more or less remarkable, depending both upon the accession and the separation of oxygene; and in many of these light has a

considerable influence in promoting one or other of these effects.

In all the instances lately mentioned, blackness was produced by a separation of vital air from the metallic basis; but there are others in which it results from the addition or accession thereof. Arsenic, as Mr. Chaptal mentions, when first sublimed, is of a shining grey, or steel colour, but blackens speedily by exposure to the air (" noircit promptement a l'air;") and he likewise observes, that " manganese, precipitated by an alkali from its solution, was found to be a whitish gelatinous substance, which soon changed colour, and became *black*, by the contact of air; that, having been a witness of this phenomenon, he could only attribute it to the absorption of oxygenous gas, and found this to be the case, by shaking the white precipitate in glasses filled with that gas, by which the black colour manifested itself in one or two minutes, and a considerable part of the gas was found to have been absorbed." Elémens de Chimie, tom. ii. p. 260.

The preceding instances relate to mineral and inorganical substances; there are many, however, which relate to the colours of vegetable and animal matters. Ray, in his Historia Plantarum, printed in 1686, vol. i. p. 15, appears to have discovered, by several experiments and observations, that the green colour of plants depended chiefly upon the influence of light: he had found that they were *green*, whilst vegetating under a transparent glass bell exposed to the light, and that when growing in obscurity under an opaque vessel, they lost their green, and acquired a pale whitish yellow; their stalks, at the same time, becoming long, slender, and feeble, and their leaves small. And these effects he ascribed to the want of light, rather than of either air or heat: " Nobis tamen non tam aer quam lumen, luminisve

actio coloris in plantarum foliis viridis caussa esse videtur."—" Ad hunc autem colorem inducendum non requiritur calor," &c. Mr. Bonnet has since confirmed Ray's conclusions upon this subject, and added several curious facts, resulting from a variety of experiments related in the fourth and fifth volumes of his works: but it is Mr. Sennebier who has done most, and carried his inquiries farthest respecting it, as appears by his "Memoires Physico-Chimiques sur l'Influence de la Lumiere Solaire," &c. in 3 vols. 8vo.

It is now well ascertained, that vegetables, growing in the light, give out oxygene gas, (pure vital air;) and Dr. Ingenhouz, by a great number of experiments, has proved, or conceives himself to have proved, that in the dark they give out the carbonic acid gas (fixed air;) though this has been doubted by others, and particularly by Mr. Sennebier, who conceives, that, in these cases, it was the pure air vitiated by some disease or decomposition of the plant itself: Dr. Ingenhouz, however, in his last publication, adheres to his former opinion, and supports it with new facts and arguments. Be this, however, right or wrong, there is no room to doubt but that healthy plants, growing in the solar light, decompose both water and carbonic acid gas; and, appropriating to themselves the hydrogene, or inflammable air (which is a constituent part of water), and the carbonaceous matter, or basis of the carbonic acid, with perhaps a small portion of the oxygene, they emit the rest in the form of vital air, which the light seems to separate, by combining with and rendering it elastic, in the same manner as it separates the oxygene from the calces or oxides of metals, &c. But when plants vegetate in obscurity, no such separation can take place: indeed, the water imbibed by the plants seems not to be properly decomposed, unless their living powers be

aided by the stimulus of light, and by its affinity for the oxygene. There is, therefore, an accumulation of this latter substance, and a want of inflammable air to compose the resinous matter, by which the green colour of the plant is produced; and this colouring matter being very sparingly formed, and at the same time combined with an excess of oxygene, the plant, instead of its natural greenness, exhibits only a white or pale straw colour. Mr. Sennebier found that plants, in this state, received a deeper green, and in less time, by exposure to the *violet* rays of light, than to those which were less refrangible, as was the case in colouring the muriate of silver. He also found that plants left to vegetate without light, under vessels filled either with nitrogene, or hydrogene, did not lose their green colour, as when surrounded by common atmospheric air. In carbonic acid gas they soon perished. Dr. Ingenhouz also observed, that on mixing a little hydrogene with either the common or the vital air in which a plant was growing, under a transparent glass, the green colour of the plant soon became deeper. In these cases there seems to have been an absorption of the hydrogene, affording an increase of the resinous colouring matter.

Mr. Sennebier also found, that the red tinctures of orcanette,* safflower, kermes, gum lac, and cochineal, were made yellow by exposure to the sun's rays; and the tincture of dragon's blood was thereby deprived of all colour: in these cases the *alcohol*, or spirits of wine, assisted the action of the sun's rays in decomposing the several colouring matters, probably by abstracting and combining with their oxygene; because it was found that the *aqueous* infusions of orcanette, kermes, and cochineal, suffered no change by the like exposure; though

* *Anchusa tinctoria.* Lin.

indeed the infusions of safflower, dragon's blood, and gum lac, were changed by it; perhaps because they contain a resinous matter which might have co-operated with the rays of light, in the same way as the spirit of wine is supposed to have done. Mr. Sennebier observed, that the petals of damask roses afforded a kind of brick colour to spirits of wine, when put into it; and that this, by a few minutes exposure to the common light, became of a fine violet colour; which, however, was soon destroyed, by a direct application of the sun's light, unless when a few drops of some of the strong acids were added; in which case, the colour withstood the sun's rays for several months. From these instances I conclude, that the colour of roses depends on a certain proportion of oxygene; that the light, aided by the affinity of the spirits of wine for oxygene, produces a separation of it, and destroys the colour; but that these effects are obviated, as might be expected, by the addition of acids containing and affording a supply of oxygene. And that this was the fact, seems evident from this observation, made by Mr. Sennebier, that when the petals of the roses had been rendered white, by imparting their colour to the spirit of wine, they regained it on being taken out, and exposed to the air, even in a dark place; though they did it much quicker in the light; but not at all in a vessel containing only nitrogene surrounded by quicksilver, even when aided by an immediate application of the sun's light; which clearly proves, that the restitution of oxygene was indispensably necessary to the restitution of their colour. In the same way *sulphureous* acid whitens roses, by depriving them of their oxygene; and the *sulphuric* acid revives the colour, by restoring it.* Mr. Sennebier also

* The sulphureous or volatile vitriolic acid, not being saturated with oxygene, is disposed to attract it from other matters in con-

found that the red skins of peaches became white in spirits of wine, like the petals of roses, and, like them, regained their colour by exposure to the air; as did also the red skins of plumbs. He likewise observed, that the water-colours used by painters, if covered by a solution of fish glue or isinglass, and then varnished, withstood the action of the sun's rays much longer than if varnished without the fish-glue; which last seems to have prevented the varnish from co-operating with the light in extricating the oxygene of the colouring matters, as, from its inflammable nature, it would do, if in immediate contact with them. Negro children when first born are white, as plants are when they first shoot above the earth, though they become *black* in a few days, after being exposed to the light, as plants become green, and probably from the same cause.

In like manner the hair of such kittens, puppies, &c. as are intended by nature to become decidedly black, is immediately after birth only of a brownish black; but it gradually darkens externally. Though the hair of the blackest cats and dogs will be found, even in old age, not to be black at the *roots near the skin*, where it is most secluded from the light.

Mr. Sennebier mentions, upon the authority of Scheele, that the Nereis lacustris, is *red* whilst living in places accessible to the sun's rays, and *white* when living in obscurity; and M. Dorthes asserts, (Ann. de Chimie, tom. ii.) that most of the *larvæ* of insects, inhabiting the dark cavities of animals, trees, fruit, &c. are white; and that having forced a variety of them to live under transparent glasses, exposed to the light, they gradually became brown. But the most *decisive* and *interesting*

tact with it; and by so doing, it not only whitens roses, but silk, wool, and other substances, rendered yellow by being united to a certain portion of oxygene.

proof of the action of light, in producing various colours by promoting a separation of oxygene from animal colouring matter, will be found by the effects which I shall notice hereafter, when treating of the celebrated *purple of the ancients.*

The preceding are examples of animal and vegetable colours produced, changed, or destroyed, either by the action, or the want of light, exerted in separating their oxygene. In many other cases, however, the affinity of light is very differently exerted, upon colouring matters, by promoting a combination of oxygene with them.

The green colour of the leaves of plants resides in a resinous substance, which being dissolved and extracted by spirit of wine, produces a green tincture; and Mr. Sennebier having exposed this to the rays of the sun, in a clear transparent glass, but half filled, he found, upon repeated trials, that the colour was generally destroyed in about twenty minutes, and a yellowish substance was precipitated to the bottom; which seems to have been the colouring matter saturated with oxygene: but when the glass was completely filled with the green tincture, and closely stopped, he found, that the strongest action of the sun's rays upon it, during four months, did not weaken in any degree, the green colour, because all oxygene was excluded, and the rays of light, without it, were unable to effect any change. When nitrogene was inclosed in a vessel partly filled with this green tincture, the latter suffered little or no change, by long exposure to the direct action of the sun's light; but if, instead of this, he substituted pure vital air, the green colour was most rapidly destroyed. Mr. Sennebier also found, that the dark red juice of black cherries very soon lost its colour, when exposed to the sun's rays, but that a tincture of those cherries in spirit of wine, preserved its colour in the same circumstances; the

spirit of wine, as I conceive, affording a covering and defence to the colouring matter of the cherries, against the action and farther combination of oxygene or vital air. Here the effect was directly opposite to that with roses, lately mentioned. M. Fabroni has also asserted, (Ann. de Chimie, tom. xxv.) that the fresh juice of the aloe succotrina angusti folia, by mere exposure to the atmosphere, either with or without the contact of light, soon became red; first, at the parts most accessible to the air, and afterwards in other parts, and that it finally became of a very dark, but very lively purple: and he convinced himself that this change resulted exclusively from an absorption and combination of oxygene. There are many other instances of changes of colour by an absorption of oxygene, with or without the assistance of light; and in particular two experiments made by M. Berthollet. In the first, he "inverted, over mercury, a bottle half full of the green solution (employed by Mr. Sennebier,) and exposed it to the light of the sun; and when the colour was discharged, the mercury was found to have *risen in the bottle*, and consequently vital air must have been absorbed; the oxygene having united with the colouring matter." In the second experiment, he "placed a tincture of turnsol, in contact with vital air, over mercury, in the dark, and he also exposed a similar tincture to the light of the sun; the former continued unchanged for a considerable length of time, and the vital air had suffered no diminution; but the latter had lost much of its colour, was become red, and the air was in a great measure absorbed," &c.

M. Fourcroy has also demonstrated, (see Ann. de Chimie, tom. v.) that a variety of colouring matters, extracted by water, and left exposed to the air, combined with its oxygene, and thereby not only assumed new colours, but became much more fixed and permanent;

which happens likewise in the production of indigo, as will be proved hereafter.

I have now noticed the principal facts respecting the powerful agencies of solar light, in producing, changing, and destroying mineral, vegetable, and animal colours; which agencies as far as we know, or can judge, seem to be principally, if not exclusively, exerted, in promoting, under particular circumstances, and with particular coloured, or colouring, matters, *an abstraction or diminution of their oxygene;* and with other matters and other circumstances, in causing a *new* or *additional combination of it.*

These *opposite* effects, may be now explained in consequence of recent discoveries respecting the sun's beams. Newton taught us, that when the rays of which they consist are transmitted through a triangular prism, and received upon white paper, those *most distinctly perceptible*, are the red, orange, yellow, green, blue, indigo, and violet; and that if the coloured image or spectrum be divided into 360 parts, the red will occupy 45 of these parts, the orange 27, the yellow 48, the green 60, the blue 60, the indigo 40, and the violet 80; and that the red are refracted the least; the violet the most; and the other rays inversely in the order in which they have been arranged, and he supposed them to vary in the size of their particles, according to this order; those of the violet being the smallest. It has, however, been recently ascertained by Dr. Herschell, (see Philosoph. Transactions for 1800, p. 267.) and by the experiments of Sir H. Englefield and others, that the solar beams comprehend three sorts of rays; viz. one which excite heat and promote oxidation, or the combination of oxygene with different matters; another which illuminate; and a third which *de*oxidize, or cause the separation of oxygene. He found the yellow, and the pale green rays,

to possess the greatest power of illuminating, and the violet the least; and the red rays to possess the greatest power of heating, and the violet the least. But beyond the *red* rays, there are certain *invisible heating* rays, which raise the thermometer higher than even the red rays. Moreover, at the other extremity, a little beyond the *violet* rays, not only the thermometer *is not affected*, but there are *there*, certain *other invisible rays*, which produce, very efficaciously, particular chemical effects; one of which is that of changing from *white to black*, the colour of a precipitate of the muriate of the silver just made. This is, indeed, done most rapidly, by the *collected* rays of the sun's beams, but the separate rays do it with greater energy, in proportion as they are nearest to the invisible rays, at the *violet extremity*. Sir H. Davy also states, that "if moist horned silver, (muriate of silver) be exposed to the different rays of the prismatic spectrum, it will be found that no effect is produced upon it by the least refrangible rays, which occasion the greatest heat, *without light;* a *slight* discolouration only, will be occasioned by the red rays; the effect of *blackening*, will be greatest towards the *violet* part of the spectrum; and in a space beyond the violet, where there is no sensible heat or light, the chemical effect will be very distinct." "This observation, (he adds) made by M. Ritter and Dr. Wollaston, proves that there are rays more refrangible than the rays producing light and heat; and from the observations of M. Berthollet, it appears that muriatic acid gas is formed, when horn silver is blackened by light, so that they may be called *hydrogenating* rays," p. 211. Sir H. Davy farther observes, in the next page, that he "found that the puce (or Flea) coloured oxide of lead when moistened, gradually gained a tint of red in the least refrangible rays, and at last became black, but was not affected in the most refran-

gible rays; and the same change was produced, by exposing it to a current of hydrogene gas. The oxide of mercury procured by a solution of potassa and calomel, exposed to the spectrum, was not changed in the most refrangible rays, but became red in the least refrangible rays, which must have depended upon its absorbing oxygene."

Dr. Wollaston found that the substance called gum-guaiacum, when exposed in the most refrangible rays, beyond the violet extremity, was changed from its yellowish colour to green; and that it was again made yellow, by the least refrangible rays. One of which effects must have resulted from a separation, and the other from an absorption of oxygene.

The oxygenating power of the solar rays is, however, that which M. Berthollet seems exclusively, and as I think erroneously, to insist upon, as occasioning, either with or without the aid of light, all the changes and injuries to which animal and vegetable colouring matters are liable; and he deems the action and effects of oxygene in these cases to be similar to those of *combustion.** "In considering the effects of air on colours (says he,) it is necessary to make a distinction between those produced by metallic oxides, and those produced by the colouring particles," meaning those of an animal or a vegetable nature; the modifications of the former are, says he, "entirely owing to different proportions of oxygene;" but I have been led by observation, he adds, "to form a different opinion of the latter;" meaning those with which the oxy-muriatic acid had exhibited

* "Cet effet doit être considéré comme *une véritable combustion.* Par là, le charbon qui entre dans la composition des parties colorantes, devient prédominant, et la couleur passe ordinairement au jaune, au fauve, au brun; ou cette dégradation en s'alliant avec ce qui reste de la premiere couleur, produit d'autres apparences."

different phenomena, sometimes discharging their colour, and producing whiteness, but most frequently rendering them yellow, fawn, or root-coloured, or brown or black, according to the intensity of its action: and he remarks, that he had found, by comparison, that when the colouring particles were rendered yellow, fawn-coloured, or brown, by the oxy-muriatic acid, effects were produced similar to those of combustion; and that they were "owing to the destruction of the hydrogene; which, as it combines with oxygene more easily, and at a lower temperature than charcoal does, leaves the latter *predominant;* so that the *natural colour of charcoal* is more or less blended with that which before existed;"* and as

* Messrs. Lavoisier, Berthollet, and other pneumatic chemists, have considered the *black* colour of charcoal as *naturally* existing in the vegetable matter from which it is formed, and not as the result or effect of combustion. To me, however, charcoal seems to be a kind of vegetable *oxide*, consisting of the carbonaceous basis, united to a certain portion of oxygene, enough to render this basis black (as it occasions the blackness of manganese,) but not enough to saturate and convert it into carbonic acid gas. Hard woods contain so great a portion of the basis of charcoal, that if it really existed therein, with its black colour, previous to combustion, it is impossible to conceive how they should ever appear white, yellow, red, &c., since in dyeing, &c. we find, that laying other colours upon a black ground, increases the blackness. Neither do I think that this blackness is the only circumstance in which charcoal differs from its basis, or the state in which the vegetable part thereof existed previous to combustion: on the contrary, its oxidation, or combination with oxygene, manifestly gives it new and very remarkable properties. This basis, is, indeed, never converted into charcoal, but by such a degree of heat, and in such circumstances, as must necessarily occasion its combination with oxygene; and when this conversion is made, the charcoal is rendered infinitely more indestructible than any other vegetable matter, as it will resist the combined action of sun, air, moisture, &c. for hundreds of years; and indeed it can hardly be destroyed, but by such farther combustion and combination with oxygene, as will change it into carbonic acid

"the light of the sun considerably accelerates the destruction of colours," he concludes that it ought, if his

gas. This indestructibility, or stability, as well as the *black colour*, of charcoal, therefore manifestly result from the combination of oxygene with its basis. Did it really exist, *with its black colour naturally* in wood and other vegetables, why do we not find it remaining *intire* after the other parts of vegetables are separated or destroyed by fermentation, putrefaction, &c.? And why does it decay and rot with them *undistinguished*, contrary to what happens when it occurs separately, in the form of charcoal? And why, when it has assumed this form, will it not recombine with matters similar to those which were separated from it, and enter with them into fermentation, &c. as it surely ought to do, if it had acquired no new property, and only been left in a distinct form, by the simple *abstraction* of those matters.

The preceding observations respecting charcoal, were first printed in the year 1793. It did not then accord with my purpose, to enter upon a minute examination of the several constituent parts of charcoal; I wished only to convince my readers that it was not a *simple* substance, *naturally* formed, and existing with its *black* colour in vegetable matter; and that when dyed colours faded, and became brown or dark coloured, by exposure to the sun and air, this change did not happen, as M. Berthollet had conceived, because the supposed *naturally black colour* of the charcoal, contained in the vegetable dyes, was rendered *visible*, and *predominant*, by a separation of the other matters, which had been in union with it, ("de sorte que la couleur *propre* au charbon, se mele plus ou moins, a celle qui préexistait." Berthollet, tom. i. p. 133). To produce this conviction, I thought it only necessary that my readers should, without bias, exercise their senses and understandings. Since that time, the nature and composition of charcoal have been nearly ascertained; but I think I may claim the merit of having first occasioned a distrust of the doctrine of M. Lavoisier on this subject, and thereby promoted the subsequent experiments and inquiries.

Dr. Thompson, one of our best systematic chemical writers, makes the following observation in the first volume of his system of chemistry, viz. "Lavoisier supposed pure charcoal to be a *simple* substance, and for that reason invented the term carbon to distinguish it. But other philosophers were of opinion that charcoal is a compound body, and that it is composed of carbon and oxygene. The truth of this opinion, *which, as far as I know, was first main-*

theory be well founded, "to favour the combination of oxygene, and the combustion thereby produced."*

In thus ascribing the decays of vegetable and animal colouring matters *generally*, to effects or changes similar to those of *combustion*, M. Berthollet has, I think, gone farther than is warrantable by facts. It cannot, I am persuaded, be his intention that we should apply the term of combustion to alterations which result from a simple addition of oxygene to colouring matters, without any destruction or decomposition of their constituent parts; though a great many of the alterations and extinctions of these colours evidently arise only from such simple additions. The nitric, sulphuric, and other acids containing oxygene, have the power not only of weakening, but of rendering latent for a time, the colours of many tingent matters; not however by any effect which can properly be denominated a combustion, but rather by a *change* in their several *affinities* or attractions, for *particular rays* of light in preference to other rays; but none of their parts being destroyed, or carried away, the addition of an alkali, or of a *calcareous carbonate*, will generally undo such alteration, and restore the original colour, by decomposing and neutralizing the acid or oxygene which had caused the alteration. Of this numerous instances might be given; it will however be sufficient to mention, what most people have seen, that ink, dropped into a glass of diluted nitric, or vitriolic acid, will lose its colour, and that it may be again restored by adding a suitable portion of vegetable or fossil alkali; and that this may be done several times with the

tained by Dr. Bancroft, has been lately established by the experiments of M. Guyton Morveau." To these have been more recently added, the accurate researches of Messrs. Allen and Pepys.

* Elements of the Art of Dyeing, chap. iii.

same ink, and therefore the change, or loss of colour, could not have been the effect of combustion. The production and existence of each particular colour, depends upon precise, and often very minute proportions of the constituent parts of the colouring matter, and it may, therefore, be changed, and in many cases even destroyed, by every thing capable of *altering these precise proportions;* and as this may be done by very opposite causes, we are not warranted in ascribing the decays of colours *generally* to combustion only, or indeed to any one cause exclusively. Many colours are as much injured by muriatic acid, as by the sulphuric or nitric: and as the former is now generally admitted to contain *no oxygene*, or to contain it *so inseparably combined*, that no combustion can take place by means thereof, we must necessarily infer, that the effects of the muriatic acid, are not occasioned by combustion, which muriatic acid does not produce.

Mr. Sennebier exposed a great variety of woods to the action of the sun and air, and found all their colours very soon affected. The white woods were generally made brown, and the red and violet changed either to *yellow* or black. *Guaiacum was rendered green;* the oak and the cedar *were whitened*, as were the brown woods generally; several of these effects, and especially the whitening, do not resemble those of combustion, any more than the *bleaching of wax and tallow*, by exposure to atmospheric air.

The colour of each particular substance results from its peculiar constitution, producing in it a particular affinity or attraction for certain rays of light, and a disposition to reflect or transmit certain other rays; and in this respect it may doubtless suffer very considerable changes, without any effects similar to those of combustion. And indeed the changes of colour which arise from the ac-

cess of vital or atmospheric air, seldom resemble those which the mere predominence of blackness (the supposed natural colour of charcoal) would produce; though this may have been the case with the colouring matter of brown or unbleached linen, upon which M. Berthollet's experiments were principally made.

But whether the action of vital air, or its basis, in promoting the decays of a few particular colours, ought to be denominated a combustion or not, I am confident that, at least, some others are liable to be impaired, *not so much by an accession of oxygene, as by the loss of it;* an effect, of which I have already enumerated several examples, among animal and vegetable, as well as mineral substances, deriving their colours from a combination with certain portions of oxygene; and of these I might easily augment the number.

Hook and Lower long since noticed the difference of colour in arterial and venal blood; and it has been since proved, by numerous experiments, that the fine vermilion colour of the former, is produced solely by vital air, which it is capable of acquiring even through bladders, the coats of blood-vessels, &c. And very recently, Mr. Hassenfratz seems to have proved (see Ann. de Chimie, tom. ix.), that as this fine red colour is gained by a dissolution of oxygene in the arterial blood, so it is lost, and the dark colour of the venal blood restored, by a separation of the oxygene.

That the blue colour of indigo absolutely depends upon a certain portion of oxygene, has been already mentioned, and I shall hereafter give some curious illustrations of this fact, from which it will appear that a solution of indigo, by losing its oxygene, may be rendered as pellucid, and, excepting a very slight straw-coloured tinge, as colourless as water, and that it will afterwards speedily return, through all the shades of

yellow and green, to its original deep blue, only by exposure to atmospheric or vital air. Similar to this is the fact long since observed by the Abbe Nollet, of the tincture of archil (orchella) employed to colour the spirit of wine used in thermometers, which after some time loses its purple colour, but soon recovers it again upon being exposed to atmospheric air. And this also happens to the infusion of turnsol, and to syrup of violets, which both lose their colours when secluded from air, and regain them when placed in contact with it.* Many other examples of the like effects might be mentioned here; but to avoid repetitions, I beg leave to refer my readers to subsequent parts of this work, in which I shall have occasion to instance various animal and vegetable colours, produced solely by the contact of vital or atmospheric air; and some others, which, when given by dyeing or calico printing to wool, silk, cotton, &c. though unable to sustain a single day's exposure to the sun and air without manifest injury, were found to receive none from the action of acids of considerable strength, but, on the contrary, were in some degree preserved by being wetted with them, and especially with the citric acid. But the same colours, if covered with linseed oil, were found to decay more quickly from exposure to the sun and air, than if uncovered. These colours therefore could not owe their decays to the contact or combination of oxygene, because they were not only unhurt, but benefited by its agency in the citric, and other acids containing it; and also because they were soonest impaired when secluded from it by a covering of linseed oil. Probably the decay of these colours was occasioned

* Oxygene is also absolutely necessary to produce the blue colour of Prussian blue, and the black colour of ink. These facts are too notorious to require proof.

by a loss of at least some part of the oxygene, necessary to their existence, and which the linseed oil assisted in depriving them of, by its known affinity therewith.

In forming systems, we are apt to draw general conclusions from partial views of facts. And this even M. Berthollet seems to have done, not only in ascribing the decays of vegetable and animal colours, *exclusively* to effects similar to those of combustion, but also in representing the oxy-muriatic acid as an accurate test or *measure* for anticipating, in a few minutes, the changes which these colours are liable to suffer, by long exposure to the action of sun and air; for though it should be true that the oxygenated muriatic acid, in weakening or destroying colours, gives up to them more or less of the oxygene, which it is supposed to have received from manganese; and that, by this new combination of oxygene, those affinities for particular rays of light upon which their colours depend, are liable to be destroyed; it is nevertheless true, that the changes of colour so produced are no certain indication of those which the *combined influence of light and air* will occasion upon colours in general; there being, as I have already observed, and as I shall more fully explain hereafter, several colours which are very speedily destroyed by the latter of these causes, though they resist the action of the oxy-muriatic acid, even longer than the best colours given to printed calicos.

M. Berthollet well knows, since nobody has contributed more to ascertain, how much the properties of oxygene are diversified by each particular basis to which it unites; and it does not therefore seem warrantable to imagine, that its action would not be *modified*, as well as increased, by a basis so powerful as that of the common muriatic acid; or that the *united properties of both*, should exactly represent or resemble those of atmos-

pheric air upon colours, any more than they do in the lungs, where, instead of supporting life, when respired, they would instantly destroy it.

Ten years after I had published the preceding observations, M. Berthollet, in the new edition of his "Elémens de Teinture," (between pages 131 and 147 of the first volume) recapitulated those parts of his former edition, which relate to this subject; and for doing so, he assigned the following motive, viz. "parceque *Bancroft, dont l'autorité est pour nous d'un grand poids*, a prétendu réfuter la théorie qui y est établie, et que nous desirons de mettre en état de *peser* ses raisons, et les motifs de notre opinion." He afterwards (p. 147 and seq.) notices some of my objections to his theory; and particularly that wherein I asserted, that colouring matters suffer, by the action of acids, and other substances, alterations which cannot be compared to combustion; to which he answers, " mais il n'est question dans les explications précédentes, que de l'espèce d'altération qui dépend de l'action de l'oxigène." This answer, were I not fully convinced of M. Berthollet's perfect candour and regard for truth, would seem to be either an evasion, or a mere petitio principii: and it certainly has the effect, of at least greatly *narrowing* the ground of our dispute; for I have never contended that *oxygene assisted by light*, does not *in some cases* injure colours in the way which M. Berthollet supposes, i. e. by combining with the hydrogene of the colouring matter, &c.; though I have objected to what seems to have been his opinion, that this was the *only way* in which the fading or decaying of colours ought to be explained; and considering the very opposite effects of light in regard to oxygene, which have been recently stated (and which M. Berthollet seems to have overlooked) it is impossible for me not to persist in that objection. It

therefore still remains for us to ascertain, and distinguish the particular cases in which oxygene, assisted by light, injures colours, by combining with the hydrogene of their respective colouring matters; but even if this were done, I should never be convinced that these matters had naturally contained ready formed *black charcoal*, and that the degradation of the faded or injured colour, resulted from a greater manifestation and *predominance* of this charcoal, with its supposed naturally *black* colour.

M. Berthollet next adverts to my objection that oxygene, far from destroying colours *generally*, is necessary to the existence of some of them, as e. g. of indigo. And to this he answers, " n'est-ce pas ce que l'on a dit? mais l'on a distingué les cas où il devient un élément de la couleur, et ceux où son action devient destructive." An answer which leaves us still to ascertain and distinguish the numerous colouring matters, of which oxygene is admitted to be an essential constituent, and which, from that circumstance, will be most susceptible of being injured, by a *deprivation* of oxygene, rather than by any addition of it; and even after this distinction shall have been made, it will not follow, as a necessary consequence, that the other remaining colours are not liable to suffer by effects very different from those of combustion.

Next in order, M. Berthollet notices my objection to his ascribing the degradation of *faded* colours, to a predominance of charcoal, since many substances contain large proportions of it, without having any such colour as has been ascribed to its *excess;* and since the colour of charcoal itself, results only from an oxygenation of its basis. To this he answers, that without entering upon a discussion of my opinion on this point, " il s'agit seulement de sçavoir, si dans les circonstances dont il

est question, le changement de couleur n'a pas de l'analogie avec celui que l'on observe, lorsque l'on distille une substance végétale;" and he seems to imagine (erroneously) that I had conceived the free access of the oxygene of the *atmosphere*, to be necessary to the browning of vegetable matter in that process, where there is otherwise, a sufficiency of oxygene. He next observes, that I had erred in supposing that his opinion was founded solely upon experiments made with the brown colouring matter of unbleached linen. But it will have been seen, that I only mentioned this as the matter upon which they "*were principally made.*"

And, finally, in regard to my objection to his assuming the action of the oxy-muriatic acid upon dyed colours, to be an *exact indication and measure* of that which they would suffer by exposure to the sun and air, he observes that he did not find in my work, an account of the experiments which I had announced, as sufficient to prove that the effects of the oxy-muriatic acid, are sometimes at variance with those of the oxygene of the atmosphere. For this last observation there may have been some little foundation; but my readers will soon find it removed. I had, indeed, *occasionally* noticed some of these experiments, though not *collectively;* and others were intended to be also mentioned occasionally, in the second volume.

M. Berthollet next admits, that in comparing the effects of the oxy-muriatic acid, with those of the oxygene of the atmosphere, it is necessary to take into consideration the *greater condensation* of the oxygene in the former, together with "*L'action particulière de l'acide Muriatique;*" which, to my understanding, he certainly did not do in regard to the *latter;* and his not doing it, was the chief foundation of my objection. Even in his last edition (tom. i. p. 68) when treating of these effects,

of the oxy-muriatic acid upon colours, he says "il agit alors *par l'oxigène qu'il abandonne*, et par conséquent *son action ne diffère que par l'intensité, de celle de l'air atmosphérique;*" so that even in this last edition, the particular action of the muriatic acid is *completely*, and as M. Berthollet now admits, *improperly* overlooked. He admits also, at p. 149, that it is necessary to distinguish between the effects produced by the oxy-muriatic acid, when *it completely discharges or extinguishes all colour*, and those due to the combination of its oxygene, with the hydrogene of the colouring matters. I do not, however, believe, that there is any such difference in its action, or that it ever relinquishes any oxygene to combine with the hydrogene of the colouring matter in question; but that it destroys colours, by a power peculiar to itself, and inexplicable by any of its sensible qualities; a power manifested by effects the very reverse of combustion, since that highly *combustible* substance cotton, is bleached and rendered perfectly *white* by it, instead of being made brown or black, as it would be, if its mode of action were such as is here supposed.

M. Berthollet afterwards brings this discussion to a conclusion, by the following partial *concession*, at p. 150, viz.

"Si nous avons cru pouvoir réfuter les objections de Bancroft, sur la cause au moins la plus ordinaire de la dégradation des couleurs par l'air et la lumière, nous convenons que *les conséquences* de l'opinion que nous tâchons de maintenir, *n'auraient pas dû être étendues aux phénomènes que nous allons examiner*, quoiqu'on ne l'eût fait qu'avec beaucoup de réserve, et sans sortir des bornes d'une simple conjecture:" and he then proceeds to an examination of the phenomena, to which his doctrine on this subject *ought not to have been ex-*

tended. Of these, the principal relates to the yellow colour produced upon wool, silk, and other *animal* substances, by the nitric acid; of which I have already given what appears to be the *only true* explanation at p. 28.

If I have sometimes thought it my duty to contest the opinions of M. Berthollet, I have always done it reluctantly, and I can feel no pleasure in prolonging, unnecessarily, a controversy with one, for whose decisions I feel so much deference, even where I believe it might be done with advantage on my side; I should, therefore, *here* terminate our discussion, were it not incumbent on me to state certain facts, which prove that the effects of the oxy-muriatic acid upon particular colours, are not an indication or measure of those changes, which would take place in the same colours, by exposure to the sun and air; and of which facts, M. Berthollet complains that he did not find a statement in the volume formerly published.

In the introductory part of my present volume, I have noticed the subsisting opposite opinions, concerning the nature and constitution of the substance, called acide muriatique oxigené, by the French chemists, and oxymuriatic acid by the British; and which Sir H. Davy has lately denominated, *chlorine.* M. Berthollet and others, who believe oxygene to be one of its constituent parts, suppose that in bleaching or destroying colours, it acts by giving up to them its oxygene. Scheele had imagined that it did this, by combining with *phlogiston*, which was then thought to be the most important part of colouring matters; and Davy, who like Scheele, considers his *chlorine* as a simple or *decompounded* substance, says (p. 243.) that it decomposes water by a double affinity; "that of the hydrogene for chlorine, and that of the colouring matters for oxygene;" to which

last he ascribes, like M. Berthollet, the destructive action of chlorine upon colours, though he derives the oxygene from a different source. But if, as is here supposed, the destruction of colours by the oxy-muriatic acid resulted solely from the oxygene, which it either relinquishes, or separates from water, its effects on colours ought to resemble those of the nitric acid, when the quantity of oxygene which they severally afford, or put into action, is the same, and the effect of each ought to be proportioned to the degree of acidity in the destroying agent. Many experiments have, however, convinced me, that few things are more unlike, than the several effects of the oxy-muriatic, and nitric acids, upon colours giving by dyeing, &c. A very few of these experiments will suffice.—I put into a small phial, cuttings from three skeins of cotton yarn, which had been dyed, and sent to me by M. Chaptal, before he was called from his chemical labours to those of a minister of state. One these had received the Turkey red, another the nankeen buff, from an oxide of iron, and the third a black, as I believe, from madder and galls, applied upon the basis of iron, dissolved by the pyroligneous acid. Upon these colours I poured oxy-muriatic acid, which had been prepared by Mr. Accum, and kept secluded from light. Its acidity was so slight as to be hardly perceptible to the taste, and, I believe, it might have been put into the eye, without causing much pain. I found, however, that in less than two minutes, the colour of the Turkey red was much impaired, and in five, the yarn throughout the greater part of its surface had become *white*, without passing through any intermediate colour: and at the end of half an hour, but a very few specks of red, less than a pin's head, were perceptible. The buff colour at that time was found to

have acquired a little body, and the black to have lost a little, but without ceasing to be still a good black.

At the same time, I put other cuttings of the same colours into another phial, and poured upon them undiluted aqua fortis, as prepared for the scarlet dyers; and I found that in a single minute the black which had withstood the oxy-muriatic acid, was changed to a buff colour, resulting solely from the *ferruginous* basis with which it had been dyed; and that the Turkey red began to exhibit the appearance of a *scarlet*, inclining to the orange; and this last, (of a *lively tint*,) became apparently its settled colour, at the end of an hour, when the buff, by acquiring more oxygene, was considerably *raised.* Here, then, was a very great diversity between the effects of the nitric and the oxy-muriatic acids, in no degree according, or proportionate to their degrees of acidity; that of the nitric acid being, I think, at least fifty, and, perhaps, one hundred times greater than that of the oxy-muriatic acid, (which being tasted, at the time when its action upon the Turkey red was strongest, and when, according to Davy's opinion, it must have already decomposed water, had not, to my taste, acquired any greater degree, of acidity,) and yet the former, could only change the *complexion* of the Turkey red to a *bright orange*, (probably by imparting oxygene to it) while the latter (not, as I conceive, by any such, or other *addition*, but by a complete *decomposition) had at once annihilated* all the colour, (leaving the cotton yarn white) as fast, and as far, as the decomposition took place; and this without any intermediate tint, which would not have been the case if the effect of the oxy-muriatic had, as M. Berthollet supposes, resembled combustion. And, on the other hand, the black, on which the oxy-muriatic acid could make but a very slight impression, was completely destroyed, (excepting the colour of its ferruginous basis) by the nitric

acid. Not unnecessarily to multiply instances of these *unequal* effects, I will barely mention, what will be stated more fully hereafter, that this slightly acid chlorine, or oxy-muriatic acid, was, by repeated experiments, found to produce more destructive effects on the fine purple of the Buccinum lapillus, than aqua fortis, or the strong undiluted oil of vitroil. Indeed, when I consider how generally and how powerfully the oxy-muriatic acid destroys animal and vegetable colours, whilst, from its very slight acidity, it cannot be supposed capable of either relinquishing, or separating from water, any portion of oxygene at all adequate to such effects, or in any degree comparable to the oxygene of the nitric acid, (and which the latter readily gives up, without producing any equally destructive effect on colours,) it seems to me as unreasonable, to ascribe this powerful agency of the former, to any portion of oxygene which it *can possibly bring into action*, as it would be to impute the death of a man, poisoned by two or three grains of the corrosive sublimate of mercury, to the single grain of chlorine or oxy-muriatic acid, which, combined with quicksilver, constitutes this sublimate.

If this chlorine be, as Sir H. Davy supposes, a simple elementary substance, it must produce its singularly destructive effects on colours, principally at least, by a power peculiar to itself, (which probably is a decomposing power,) and if it be, as M. Berthollet supposes, a compound, (of oxygene and muriatic acid) its peculiar energies must result from its composition; from the combined agency of its constituent parts, and not from the action of either separately, as has been supposed. And it may be presumed, that the same peculiar decomposing power, which enables the oxy-muriatic acid to annihilate colours with such extraordinary celerity, enables it also (by decomposition) to weaken and injure the texture of

wool and other animal fibres, as it is known to do, in a much greater degree than the incomparably stronger sulphuric and nitric acids.

It now only remains for me to mention a few of the instances within my knowledge, proving that the action of the oxy-muriatic acid upon colours, is not an indication or measure of that which they would suffer, by exposure to the sun and air; and these instances I will select from an experiment, which was made carefully, and so recently as the 8th of July, 1812; when I put into an empty, glass-stopped phial, the following colours, upon separate bits of muslin, viz.

1st. A fast madder red dyed topically, by an eminent calico printer, upon a basis, from acetate of alumine, applied by the block.

2d. A fast yellow, dyed from weld upon the same basis, by the same calico printer.

3d. A fast yellow, dyed upon the same basis, from quercitron bark.

4th. A fine durable purple produced by the colouring matter of the buccinum lapillus, of which a full account will be given in the proper place.

5th. A logwood purple produced by mixing, with a strong decoction of that wood, as much muriate of tin, as rendered the former slightly acid, and after thickening the mixture with gum arabic, applying it in spots to muslin, which, after being properly dried, was washed with soap and water.

6th. A full bright yellow produced from a similar decoction of the quercitron bark, rendered slightly acid by an admixture of nitro-muriate of tin, made with two parts of nitric, to one part of muriatic acid, gummed, and topically applied in the same manner as the logwood purple, and in like manner dried, and afterwards washed.

7th. A similar yellow made from the quercitron bark, only substituting murio-sulphate of tin, for the nitro-muriate. Upon these colours I poured oxy-muriatic acid, with which Mr. Accum had recently supplied me, (and which I had kept secluded from the light,) until the phial was full; after which, in less than two minutes, I found that the bits of muslin, with the *madder*, *weld*, *and quercitron*, colours dyed upon the *aluminous* basis, were become perfectly white, by a complete extinction of their several colours. Whilst the logwood purple, that from the the buccinum, and the quercitron yellows, with solutions of tin, were not apparently changed. But in about five minutes the logwood purple appeared to be losing body, as did the quercitron yellows soon after; and a similar effect soon became evident in the shell purple.

In about fifteen minutes, from the time when these colours were immersed in the oxy-muriatic acid, the logwood purple had nearly disappeared; and this was the case of the quercitron yellows in about three minutes afterwards, and of the shell purple about two minutes later; excepting that a part of the latter, as well as a part of one of the yellows given with tin, had each preserved a portion of colour, by having been protected, by other bits of muslin, from the sun's rays, which, as the sky was clear, had had free access to the phial containing them, at the window where this experiment was made; a fact which manifested the influence of solar light, in promoting the destructive action of the oxy-muriatic acid, on the colours in question.

It is here to be recollected, that the three first mentioned colours, dyed upon the aluminous basis, would have resisted the action of sun and air for two or three months, and the madder for a much longer time, and yet they were completely destroyed in an eighth part of the time which was required to destroy the logwood purple,

and the yellows with tin; neither of which could have been exposed to the sun and air for a single week, without becoming of a faded brown. It is also worthy of observation, that the Tyrian, or shell purple, was destroyed by the oxy-muriatic acid, almost as soon as the logwood purple and quercitron yellows last mentioned, though it would have resisted the sun and air, probably fifty times longer than either of them.

The property by which certain matters decompose solar light, reflecting or transmitting some, and absorbing other rays, so as to produce the sensations or perceptions of particular colours, often depends upon precise, and nice proportions in the constituent parts of these colouring matters, which proportions may be altered, and the colours resulting from them destroyed or changed by various means, acting even in opposite ways.

Oxygene from its ubiquity, as a part of the atmosphere, and its powerful agencies, co-operates in almost all the the changes which take place on, or above the surface of the earth, and especially in those connected with either the production or the destruction of colours, and its presence as a *constituent part* of colouring matters, seems to be essentially necessary to those peculiar attractions, or affinities, which, by their effects upon the rays of light, occasion the perceptions or sensations of colour. This will be abundantly proved, and elucidated by the highly instructing and interesting facts to be stated hereafter, concerning indigo.

But though combinations of oxygene in certain proportions, are necessary to the existence of most, if not of all, colours, an *excess* of it may obstruct all manifestation or appearance of colour, as completely as the *total absence* of it does, in regard to indigo. Of this a *signal* instance, and illustration, will be found hereafter, in the colourable matter of the Buccinum producing the ancient or shell purple; and

this last, as I have already intimated, will moreover afford a most curious demonstration, and exemplification, of the influence of solar light, in one, and that the most common of the ways in which it acts upon colouring matters; I mean that of separating or causing an abstraction of their oxygene: and it will be readily perceived that these *colourable* matters (of indigo, and of the shell purple,) become the more interesting and instructive, by reason of their *opposite* conditions and analogies.

To ascertain by well-directed experiments, made upon the several dyeing drugs, and the colours produced by them, with their usual or most suitable mordants, or bases, in which of the ways lately mentioned, or in what other ways, their several colours are most liable to suffer injuries or decays, would doubtless contribute greatly to improve the art of dyeing, by enabling us to employ the means proper for obviating or correcting their respective defects, so as to render colours permanent, which have hitherto been deemed fugitive; and, perhaps, increase the durability and beauty, even of those which are considered as permanent.

With this persuasion I have, at different times, projected various experiments, calculated to ascertain the effects of the sun's rays, upon colouring matters, in all their usual combinations, when placed *in vacuo*, and also when immersed in the several kinds of air, and in alcohol, unctuous, and essential oils, diluted acids, and alkalies, in order to ascertain the effects of these different agents or applications, upon the several colours; and also as far as might be practicable, to discover what each had either lost or gained by such treatment. But from the number and variety of my other unavoidable avocations, and interruptions, my progress in these experiments (excepting a few which will be mentioned in their proper places) has not been sufficient to warrant those *ultimate* conclusions,

which could only be safely and properly drawn, after an examination and comparison of the *whole;* and as I may not live or find leisure to execute the whole, I can only recommend the subject to those who may have sufficient time and qualifications for a due investigation of it.

Until further discoveries, therefore, shall have been made, I consider myself as only authorized to conclude, that the *permanent* colours of matter do not depend upon the thicknesses, sizes, or densities of its parts or particles, but upon certain affinities or attractions, physical, or chemical, by which it is disposed and enabled to absorb and conceal some of the rays of light, and to reflect or transmit other rays, producing the sensations or perceptions of particular colours; and that to the existence or energy of these affinities, or attractions, certain portions of oxygene are generally necessary, as a constituent part of colouring matters; and these portions may in some instances be increased, and in others diminished, by the influence of *radiant matter*, or solar light, which may thereby contribute to the production of some, and the destruction of other colours.

Should I be desired to assign a reason or cause for these affinities, and their connexion with particular proportions of oxygene, I can only answer with M. de Buffon, that they who require the reason of a *general effect*, do not consider the infinite extent of nature's operations, nor the confined limits of human understanding.

CHAPTER II.

Of the Composition and Structure of the Fibres of Wool, Silk, Cotton, and Linen.

"Ubi natura desinit nobis incipiendum."

Before I treat of the communication or production of colours by dyeing or calico printing, it will be proper to inquire concerning the particular natures and differences of wool, silk, cotton, and linen, upon which these operations are usually performed. The two first are animal, and the latter are vegetable substances, differing from each other in their constituent parts and chemical properties, as well as in structure and organization. M. Berthollet has greatly contributed towards ascertaining their *chemical* differences, which seem principally to depend upon a much larger proportion of nitrogene, and also of hydrogene, in the animal, than in the vegetable matters: and as the nitrogene and hydrogene readily assume an elastic form, the wool, hair, and silk, in which they abound, have less adhesion between their constituent parts, than that which exists between those of cotton, and linen, and they are, therefore, more strongly disposed, than the latter, to combine with other substances, when brought into contact with them; and it is, I believe, partly in consequence of this disposition that wool, hair, and silk, manifest stronger affinities or attractions for colouring matters generally, than cotton, and linen.* They

* *e. g.* Cotton and linen will neither of them receive any colour by the same preparation, and in the same liquor, which dyes wool or woollen cloth scarlet. This is every day seen by the cotton edges with which some some sorts of cloth are wove, which remain white after the rest of the cloth is become scarlet. M. Dufay caused a piece of cloth to be manufactured, of which the chain was wool, and the woof cotton. This was afterwards fulled, that both

are also more readily decomposed, or injured by acids, alkalies, and other chemical agents, which ought therefore to be very sparingly used in the dyeing of animal substances: it being found that the sulphuric, nitric, and muriatic acids readily *decompose* wool, hair, and silk, and at the same time destroy, or greatly weaken the texture and connexion of their several fibres; and that alkalies prove equally injurious, *by combining* with them: though silk is indeed not so liable to be acted upon in these ways, because it partakes in some degree of the vegetable nature. Animal fibres, also, contain more oil and less of the basis of charcoal than the vegetable.

It is from the superior chemical affinities, or attractions existing in wool, hair, and silk, for colouring matters, that the facilities with which these substances receive, and permanently retain colours, principally result; though something is doubtless to be ascribed to the differences of conformation, existing between their fibres and those of cotton and linen, which I shall notice under their several heads.

Article I.—*Of Wool.*

The value of this substance, and its fitness for the different kinds of manufacture, depend in a great degree on the length and fineness of its fibres; of which ample information may be found in a Memoir written by M. d'Aubenton, and printed among those of the Royal Academy of Sciences, for the year 1779. Wool is liable to great variations in quality, not only from differences in each particular race or breed of the sheep, from which it is taken, but also of the parts of the body to which it has adhered; that which covers the tails, thighs, and bellies,

might be brought into a similar state of preparation; and the cloth being then dyed by the usual process, the woollen threads contained in it received a good scarlet, whilst the cotton remained white.

being always coarser, and less susceptible of receiving colours by dyeing. It also frequently suffers in quality, and in colour, by the diseases to which sheep are liable; the most healthy of the same flock, always affording wool which is of a better quality than that of the unhealthy; and which has also a greater affinity for colouring matters, and imbibes them more copiously by dyeing.

Wool is naturally covered by an unctuous substance, which probably is destined to secure it from the injurious effects of moisture. This substance (called *yolk* by the English, and *suint* by the French,) appears, by the experiments of M. Vauquelin, (Ann. de Chim. tom. xlvii. p. 276.) to consist principally of a sort of animal soap, (having potash for its basis,) a greasy matter resembling suet, and a portion of lime in combination with the carbonic, acetic, and muriatic acids.

To prepare wool for dyeing, this yolk is commonly removed, by scowering, or maceration for a quarter of an hour, in warm water, mixed with a fourth part of stale urine; stirring the wool frequently by sticks, and afterwards rincing it thoroughly, if practicable, in running water. M. Vauquelin, however, thinks it may be advantageous, after wool has been cleansed from every thing which clean water can remove, to soak it for a few hours, *not* in diluted stale urine, but in a *tepid* solution of soap, employing one pound of the latter, with a sufficient quantity of water, to every twenty pounds of wool to be scowered. M. Roard, director of the dyeing department of the French Imperial manufactories, thinks, that one pound of Flanders soap employed in this way, is sufficient for thirty pounds of wool; but instead of a tepid solution he recommends one that is heated; though not above 60° of Reaumur; equal to about 160° of Fahrenheit.* He also re-

* M. Berthollet, in the last edition of his Elements, tom. i. p. 175, appears to think, that the substitution of soap for the ammonia con-

commends the spinning of wool in the yolk, and scowering it afterwards; when he says, it will become much whiter than if scowered before the spinning. Another advantage results from postponing this scowering, which is that of preserving the wool from the depredations of moths, and other insects, so long as it retains the yolk; an effect which Reaumur observed, and published in the year 1738. (See Mem. de L'Acad. Re. des Sciences for that year.) The wool of healthy sheep is always more copiously provided with yolk than that of the sickly.

When wool has been spun and wove, it commonly undergoes the operation of *fulling*, which I shall notice, because it depends upon such a *peculiarity* in the structure of its fibres, as seems to increase its fitness to imbibe and retain colours by dyeing. Fulling, according to Sir William Petty (see Spratt's History of the Royal Society,) "is making the cloth to become thicker, with the diminution of its other dimensions, and the covering of its threads, so as that the cloth shall seem to be translated from the likeness of a *tela*, (all of whose threads appear) to that of a *hat*, which has no threads at all; for, by the way, the making of a hat (continues he) is the making of a tela, without spinning or weaving, by a kind of fulling." "This thickening," he adds, "is made by the shortening of threads;" an effect which he erroneously ascribed to the heat of the mill, and the supposed *astringent* operation of urine, fullers' earth, &c.

tained in stale urine, has not been found advantageous in the trials made with it: M. Chaptal, however, in the fourth vol. of his Chimie Appliquée aux Arts, p. 423, treating of this operation, says, that in Spain, and recently in France, cloths have been scowered without either stale urine or soap, by preserving the water impregnated with the *yolk*, resulting from one operation, and employing it for a second; and that of the second, for a third, &c. until it becomes so thick, and overcharged with yolk, as to be unfit for use.

M. Monge has, however, lately given a better account of the operations of felting and fulling, (see Ann. de Chimie, tom. vi. p. 300, &c.) by which it appears, that the "shortening of threads" is not produced by heat, or by any astringent power whatever, but an effect resulting from the external conformation of the fibres of wool, fur, &c. which appear to be formed, either of small laminæ placed over each other in a slanting direction, from the root towards the end or point of each fibre, like the scales of fish, lying one over the other, in succession, from the head to the tail; or of zones, placed one upon another, as in the horns of animals; from which structure each fibre, if drawn from its root towards the point, will pass smoothly through the fingers; but if it be drawn in a contrary direction, from the point towards the root, a sensible resistance, and tremulous motion will be felt by the fingers. This conformation disposes the fibres of wool to catch hold of each other, and as they cannot recede, when acted upon by other bodies, they naturally advance, by a progressive motion, towards, and beside each other, from the end towards the root; a disposition which is very inconvenient to spinning, and therefore the wool is greased, that the asperities arising from this structure of its fibres may be thereby covered, or sheathed, as a covering of oil sheathes those of a file. But the wool being manufactured, and the grease no longer useful, it is removed by scowering, not only for the sake of cleanliness, but that it may not frustrate the process of dyeing. The cloth is therefore carried to the fulling mill, and there subjected to the action of large beetles, with fullers' earth and water, by which the cloth is not only scowered, but its fibres, in consequence of the structure just described, being made to conjoin, and advance toward, and beside each other, become shorter, and more closely connected, or felted to-

gether, the warp and woof losing in extent, but gaining proportionably in thickness.

The laminæ, or zones, under consideration, afford many interstices in the fibres of wool, suited to receive and contain the particles of colouring matters, when applied to them in the operation of dyeing; but these interstices being small, and the fibres of the wool naturally elastic, no colour can be conveyed into these cavities, until they are dilated by hot or boiling water; whereas silk, cotton, and linen, are made to receive colours without heat, as permanently as with it. And this difference manifestly arises from the smallness of the interstices in which the colouring particles are deposited in the fibres of wool, and their elasticity; and as the colouring particles are only made to enter and deposit themselves by an artificial dilatation, it follows that, when this ceases, the filaments will again contract to their former size, *upon* the colouring matters so introduced, and hold them much more strongly than they are likely to be held in other substances, whose interstices are large enough to receive colouring particles without being dilated, and which, therefore, cannot be supposed ever to contract and compress them in the same way: and this difference, joined to the superior chemical attraction of animal fibres for colouring matters, will sufficiently explain why many colours dyed upon wool prove so much more durable than upon cotton or linen. Wool, when dyed in the fleece, takes up much more colouring matter than when spun, and much more than when wove into cloth. It is also more or less penetrated, according to the fineness of its own texture, and the particular nature of the colouring matter with which it is dyed: the very finest cloth is never *thoroughly* dyed scarlet, it being always found white within when cut.*

* The late Mr. Nash, and his successor, Mr. Dymock, in Gloucestershire, by causing broad cloths to be wove of threads but *little*

Wool taken from different breeds of sheep, in various countries, is naturally of different colours; as white, yellow, reddish, and black. Formerly, all the flocks in Spain, excepting those of Andalusia, were of this *last* colour, it having been preferred for wearing by the Spaniards; and this natural (brownish) black is even at this time manufactured, and worn constantly by some religious orders in Roman Catholic countries. The white wool, however, is now almost universally preferred to every other, as being susceptible of receiving even a better black by dyeing, than any which is natural. The cloth worn by *Martial*, appears to have received none but the *natural* colour of the wool, whatever that may have been. He says (xiv. 133.)

> " Non est lana mihi mendax, nec mutor ævo
> ———————— me mea tinxit ovis.

And Virgil, in predicting the auspicious events which were supposed by him to follow the birth of Marcellus, (nephew to Augustus), mentions the sheep as *naturally* producing wool, of the richest and most brilliant colours.

> " Nec varios discet mentiri lana colores:
> Ipse sed in pratis aries jam suave rubenti
> Murice, jam croceo mutabit vellera luto.
> Sponte sua sandyx, pascentes vestiet agnos."
>
> ECLOGUE iv.

The lutum of the third of these lines appears to have been the Reseda luteola, or weld plant, now used as a yellow dye, and it has been conjectured by professor Beck-

twisted in the spinning, have succeeded in making their scarlet dye penetrate farther into the cloth than would otherwise have been practicable; perhaps also this difference of twisting may contribute to the remarkable beauty of their scarlets, by an alternation in the affinity of light.

man, that the *sandyx* of the last line, which is represented as giving a *red* colour to the wool of the lambs feeding upon it, must have been the madder, which is known to have grown *wild* in many parts of Italy. Its leaves are said to impart a reddish colour to the milk of cows, when eaten by them, and the roots notoriously stain the bones of hogs of a bright red, when they make part of the food of these animals.

Article II.—*Of Silk.*

This consists of the fine threads composing the follicle of the Pupa, of the Bombyx Mori, a Moth or Phalena belonging to Linneus's third order of insects. (Lepidoptera.)

It has been said and believed, that silk was exclusively produced in *China*, until the reign of the Greek Emperor Justinian. But of this there is no sufficient evidence. Pliny, indeed, after describing the countries inhabited by the Scythians, mentions the *Seres* as being the first or nearest civilized people beyond those regions; and he adds, that they were famous for the fine wool *combed from* their trees, of which he gives some account, so indistinct, however, that we may doubt whether it does not relate to cotton, rather than to silk.* But there is a passage much less equivocal in his eleventh book, (Chap. 22,) where he mentions a kind of insects, greater than the wasps and hornets which he had just before described, and to which he gives the generic name of Bombyx, adding that they are produced in *Assyria;* and after a fabulous account of the nests and honey, which he sup-

* "Primi sunt hominum, qui noscantur, *Seres*, lanicio sylvarum nobiles, perfusam aqua depectentes frondium canitiem: unde geminus fœminis nostris labor, redordiendi fila, rursumque texendi. Tam multiplici opere, tam longinquo orbe petitur, ut in publico matrona transluceat." Lib. vi. cap. 17.

posed them to make like bees, he says, they engender in a different manner; i. e. from worms which put forth two horns; that these are *Erucæ*, and afterwards change to Bombylii, then to Necydali; whence, after six months, they become Bombyces, spinning and weaving webs like those of spiders, to make garments for luxurious women, which (garments) are called Bombycina. He adds, that the first who found means to unweave these webs, and weave them again, was a female of *Cos*, named Pamphila, the daughter of Latous, who ought not to be defrauded of the honour of inventing a species of clothing, through which women may expose their beauties, as if they were naked.*

Though this account is manifestly incorrect, as well as imperfect, there can be no doubt of Pliny's intention to describe the moth of the silk worm, and its passage through the larva and pupa states; but I do not think that in his time the Romans always distinguished silk from cotton, as the terms bombyx, bombycina, and sericum, were sometimes applied to muslin and other cotton cloths, as well as to those of silk, and indeed the garments which Pliny, in his next chapter, mentions as being made of the silk produced by the Bombyx of *Cos*, (which he represents as different from the *Assyrian*,) must have been cotton. *These*, he says, even the men were not *ashamed* to wear in the *summer*, when, contrary to ancient manners, they thought *themselves overloaded* by any other than light *clothing*. He adds, however, that the men had not in his time begun to wear the *Assyrian* silk, but had

* "Et alia horum origo e grandiore vermiculo, gemina protendens sui generis cornua: hi erucæ sunt: fit deinde, quod vocatur Bombylius: ex eo Necydalus, ex hoc in sex mensibus Bombyx. Telas araneorum modo texunt ad vestem luxumque fœminarum quæ bombycina appellatur. Prima eas redordiri, rursusque texere invenit in *Ceo* mulier Pamphila Latoi filia, non fraudanda gloria excogitatæ rationis, ut *denudet* fœminas vestis."

left it to adorn females exclusively. "Nec puduit has vestes usurpare etiam viros, levitatem propter æstivam: in tantum a lorica gerenda discessere mores, ut oneri sint etiam vestes: *Assyria tamen bombyce adhuc fœminis cedimus.*"

It seems difficult to ascertain what nation Pliny intended to describe under the name of *Seres*, there being no proof that in his time the Romans had ever heard of China; though we have good reason to believe, that the manufacture and use of silk were introduced among the Chinese at a very remote period. We are indeed informed, that the annals of China mention the wife of an emperor, named Hoagti, as the first person who employed herself in spinning silk, produced by silk worms in their wild or natural state. But this was probably done as soon in other countries, and especially in Persia, where both the white and black mulberry trees where indigenous. Mr. Colebrooke informs us, that in the *most ancient Sanscrit* books there is frequent mention, not only of silk, *but of an Indian class, whose occupation was to attend silk worms.* See Asiatic Researches, vol. v.

It is indeed probable, that the very small portion of silk which had found its way to Rome, in or before Pliny's time, came not from China, but Persia; whence the Greeks, who returned from the army of Alexander the Great, appear to have first brought wrought silk into Greece, about 223 years before the Christian Æra: and the emperor Heliogabalus is said to have been the first person who, about 440 years afterwards, wore a *Holosericum*, or garment composed entirely of silk, which commodity was then rarely sold for less than its weight in gold: and it is related, I think, by Nopiscus, that the emperor Aurelian resisted the earnest solicitations of his empress, for a robe of silk, as being too costly.

But about the year 550, two monks brought from

India to Constantinople a quantity of the eggs of the bombyx mori, which they had carefully deposited in hollow canes; and the eggs being hatched by the warmth of a dunghill, and the larvæ fed on the leaves of wild mulberry trees, the insects, under the protection of the emperor Justinian, were rapidly multiplied in the Peloponnesus, and other parts of Greece;* whence they were afterwards carried to Sicily, and several parts of Italy. In the 13th century, the Venetians established very extensive manufactories of silk, in their territories, as did the Florentines in the next century. Afterwards, the Moors introduced silk worms, and the manufacture of silk, into the southern parts of Spain, particularly Murcia, Grenada, and Cordova, whence silk stockings were brought over to our Henry the 8th, and Edward the 6th. Henry the 2d of France, is said to have been the first person, who wore silk stockings in that kingdom, (at the marriage of his daughter, and that of his sister;) and we are told, that a pair of black silk stockings, having been presented to Queen Elizabeth, she was highly pleased with them, and resolved never afterwards to wear any other than silk stockings.

Though the silk of the *Bombyx mori*, greatly excels that of other moths, by its abundance, pliability, and brilliancy, as well as the facility with which it may be reeled, it is not the only production of this kind, capable of being made useful to mankind.

The Phalena Atlas Lin. produces in China very large cocoons, and their silk is remarkably strong, but being difficult to reel it is commonly spun.

The Phalena Cynthia, (or *Arrindy* silk worm,) also, is a beautiful moth, of which the natives of the interior, north-eastern part of Bengal, breed great numbers, as

* See Procopius, lib. iv. cap. 17, de Bello Gothico.

they do of the common silk worm, in a *domestic* state. Its caterpillar is very large, and feeds voraciously on the leaves of the common Ricinus, or Palma Christi. The cocoons of this moth, according to Dr. Roxburgh, "are remarkably soft and white, or yellowish, but the filaments are so exceedingly delicate, as to render it impractible to wind off the silk: it is therefore spun like cotton. The yarn thus manufactured, is wove into a coarse kind of white cloth, of a seemingly loose texture, but of *incredible durability;* the life of one person, being seldom sufficient to wear out a garment of it; so that the same piece descends from mother to daughter." It must, however, be washed only in cold water, for if put into that which is boiling, it will "tear like old rotten cloth."

Dr. Roxburgh also describes another silk worm, the Tussach, or Phalena Paphia, which is "found in such abundance over many parts of Bengal, and the adjoining provinces, as to have afforded to the natives, from time immemorial, an abundant supply of a most *durable* coarse dark-coloured silk, commonly called Tussach silk, which is woven into a kind of cloth, called Tussach doot'hies, much worn by Bramins and other sects in India." This cloth, as the doctor thinks, might "be highly useful to the inhabitants of many parts of America, and the south of Europe, where a *cheap*, light, cool, durable dress, such as this silk makes, is much wanted." See the Transactions of the Linnæan society, Vol. —, p. 33, &c.

Silk is naturally covered with a kind of varnish, or gummy substance; and almost the whole of that known in Europe, is moreover tinged of a yellow colour, which, for most purposes, it is necessary to remove, as well as the varnish. This is commonly done by submitting it to the action of soap, in circumstances which M. Berthollet has described, as well as some other means for answering this double purpose. (Tom. i. p. 184, &c.)

M. Roard, (director of the Imperial French dyes, at the Gobelins) has lately ascertained, that besides the gummy and colouring matters, there is a substance, much like wax, to be removed in this operation, (decreusage.) He states the gummy matter, as commonly amounting to twenty-three or twenty-four per cent. of the silk, and to be soluble in water: and the colouring matter to make about a 55th, or 60th part of the silk. It is very soluble in alcohol, but not in water. The wax seldom exceeds the hundreth part of the silk, and is often not more than half so much. All these matters may, he thinks, be removed with better effect, by soap than by soda: and as silk by long boiling, after it has been made white, often becomes yellow again, and is moreover hurt in its texture, M. Roard thinks, that instead of employing the soap *partially*, or at different times, as has been frequently practised, it is best *at once* to employ the whole quantity likely to be wanted, and thereby shorten the time of boiling to an hour, or an hour and one half; which will commonly suffice, and leave the silk with more of its natural lustre, and greater softness, as well as strength. M. Roard, indeed, thinks, that when silk is to be dyed of a crimson, or any other colour, to which its natural yellow would not prove unsuitable, it is best not to remove the *latter* completely, because, when this is done, the dyed colour is commonly found to have less brilliancy, than it would otherwise have had.

When silk has been freed from both its gummy varnish, and its yellow colour, it is sometimes necessary to whiten it still farther, by the fumes of sulphur applied to it, and confined in a stove. But though sulphureous acid gas, applied in this way, readily whitens the silk, and thereby renders it more fit to exhibit lively colours, a portion of sulphur adheres to it, which, when it is intended to be dyed, must be removed by soaking and agitation, for a considerable time, in warm water, that it may not

tarnish the colours; an effect which sulphur generally produces, to those of wool and silk. The lustre so much desired, in colours dyed upon silk, seems, in a great degree, to depend upon its smooth glossy surface, which acids, alkalies, and other chemical agents (particularly the solutions or oxides of tin,) contribute to impair, and are therefore to be sparingly used.

Silk, in its disposition to receive, and retain colours for dyeing, seems to partake of a middle nature, between that of the animal and vegetable substances: by its abundance of nitrogene, and hydrogene, it possesses, like wool, a strong attraction for colouring matters; but its fibres having neither a similar organization, nor an equal degree of elasticity, it is capable of imbibing colours, like linen and cotton, without any previous dilatation of its pores by hot water, but, like them, it parts with colours, so imbibed, the more easily, in consequence of this natural openness, or the want of contraction, in its pores; though, upon the whole, colours dyed in silk are more lasting, than when dyed in linen and cotton, on account of its greater affinity with colouring matters, which seems to result from its animal nature.

In the year 1709, Mr. Bon, First President of the Chambre des Comptes, aides, et finances, at Montpellier, communicated to the Royal Society of that city, a discovery which he had made of a new kind of silk, from the very fine threads, with which several species of spiders entwine their eggs; which threads were found to be much stronger than those composing the spider's web. They were easily separated, carded, and spun, and then afforded a much finer and stronger thread than that of the common silk, though somewhat less glossy. They were also found capable of receiving all the different dyes, with equal facility. Three ounces of this new silk, made a pair of durable stockings of the largest size; and as the spiders were

much more prolific, and much more hardy than the silk worms, great expectations were formed, of benefit from this discovery. M. Reaumur, therefore, took up, and prosecuted the inquiry with zeal. He conceived that, when spiders were artificially multiplied for the production of silk, it would be impossible to provide them sufficiently with flies, their natural food. This obstacle, however, was soon removed, by his finding that they would subsist very well, upon earth worms chopped, and upon the soft ends or roots of feathers. But a new obstacle arose from their unsocial propensities, which proved insurmountable; for though at first they seemed to feed quietly, and even work together, several of them at the same web, yet they soon began to quarrel, and the strongest devoured the weakest, so that of two or three hundred, placed together in a box, but three or four remained alive after a few days; and nobody could propose to keep and feed each separately. M. Reaumur found their silk to be naturally of different colours; particularly white, yellow, sky blue, grey, and coffee-coloured brown. See Hist. et Mem. de l'Acad. Royale des Sciences, ann. 1710. See also a Dissertation by M. Bon, "sur l'utilité de la soye des Arraignées." 8vo.

Article III.—*Of Cotton.*

This is the well known production of a genus of plants, denominated *Gossypium;* of which Linneus has described five species, viz. G. herbaceum, G. arboreum, G. hirsutum, G. religiosum, and G. Barbadense. To these, five other species have been added, partly indeed by elevating to the rank of distinct species, several which had previously been considered as merely varieties of some of the former. This addition consists of G. Indicum, G. micranthum, G. vitifolium, G. latifolium, and G. peruvianum. But as the specific characters of these several species are not connected with the subject of dyeing, or calico

printing, a particular account of them would be here superfluous. The fibres of cotton differ not only in their length, fineness, and strength, but also in their colours.

Most of the species of Gossipium, produce cotton which is naturally white, though a few produce it of other colours, of which that called *Nankin* by the English, and "coton a couleur *rousse* (de Siam)," by the French, is best known. Von Rohr, who was employed by the Danish government as a botanist, during ten years, in the West Indies, has described three species of this *Nankin* cotton,* which he distinguishes chiefly by peculiarities in their respective seeds.

Cotton of this colour has been long cultivated in China, and more especially along the sea shores of the south-eastern part of the province of Kiang-nam, of which Nankin is the capital, as it formerly was of the Chinese empire. It is also now cultivated at Malta, and in some of the West India islands, and is said to grow naturally in Africa. It is asserted, that a species of cotton, naturally of a *bright yellow* colour, is produced in *Dahomy*, but that the exportation of it is prohibited, by the government of that part of Africa. Mr. Clarkson has mentioned a species of cotton, naturally of a *crimson* colour, as also growing in Africa, particularly in the *Eyeo* country; of which a small specimen was brought to Great Britain in the year 1796. He adds, that "the value of this cotton would be great, both to the importer and to the manufacturer of muslins;" that "the former would immediately receive eight shillings the pound for it, and the latter would gain considerably more by his ingenuity and taste."

Lieutenant Matthews also, in describing the several

* See "Anmerkungen ueber den Cattunbau, zum nuzon der Daenischen Westindischen Colonien, &c. von J. P. B. Von Rohr." Altona, 1793. 2 vols. 12mo.

species of cotton produced at Sierra Leone, mentions one, of a pale red or pink colour: and the late Mr. Bryan Edwards, in his History of the West Indies, (vol. iii. p. 199, 8vo.) mentions, as growing wild in the Spanish part of St. Domingo, "a species of cotton of which the wool is *reddish.*"

Cotton offers to the industry and wants of mankind a filaceous substance, which, without the tedious artificial preparation required for hemp and flax, has, during many ages, especially in warm climates, constituted the most useful, as well as ornamental and graceful parts of their clothing. Whatever obscurity or uncertainty there may be in some parts of Pliny's History, relating either to silk or cotton, there is but little of either, in his account of the cotton of Upper Egypt,* growing on a *shrub*, which some (says he) call Gossipium, other Xylon, and the cloth made of its wool, Xylina. It is but small, and produces a fruit resembling the bearded nut, (filberd) from whose interior capsule, a fine wool is spun, which no linen can excel in softness and whiteness. Of this, he adds, are made those *sacerdotal* garments, in which the priests of Egypt greatly delight.

Vossius thinks Gossipion, or Gossypium, to have been an Egyptian word; the Greek name of cotton (Xylon) was abbreviated from Eryxylon, which signified *tree wool;* and the German, Dutch, Swedish, and Danish names of cotton, have this signification. The Arabian name is *cotum;* and the English and French, probably, became acquainted with it, by joining in what were called the Holy

* Superior pars Ægypti in Arabiam vergens, gignit fruticem, quem aliqui Gossipion vocant, plures Xylon, et ideo lina inde facta Xylina. Parvus est, similemque barbatæ nucis defert fructum, cujus ex interiore bombyce lanugo netur: nec lina sunt ei candore mollitiave preferenda. Vestes inde Sacerdotibus Ægypti gratissimæ." Lib. xix. cap. i.

wars, and changed it to *cotton*, and *coton*. The Italians also borrowed their name of cotone from the Arabs, and their other name of bombagia, from that of bombax, one of the names, by which the Latins designated the wool-bearing trees, "*arbores lanigeræ*" of Pliny, who, in his twelfth book, chapter 3, notices a *second* time, these *wool-bearing* trees in the country of the *Seres;* but so ambiguously, that I cannot help wondering, how it should have been so generally believed, that the Seres were Chinese, and that silk, rather than cotton, was in Pliny's contemplation, when he mentioned the wool of their trees.* The important benefits derived to mankind from the different species of cotton shrubs, have caused them to be cultivated more extensively perhaps than any other vegetable. In China, it is planted from Canton to Pekin, and from the western shores of that empire, to the deserts adjoining to Hindostan; and also along the coasts of the two Indian Peninsulas, with those of Arabia, and throughout the Mogul empire, and the innumerable islands of the Indian ocean. It appears to have been known from the remotest times, of which we have any account, in Persia, Hindostan, Egypt, and Æthiopia;† and was found, also, by Columbus, and succeeding adventurers to America, in all

* Mr. Barrow, in a note to p. 436, of his travels in China, makes the following observation, " Ptolomy the geographer, places *Serica*, adjoining to Scythia *extra Imaum*, corresponding with Cashgar, Tangut, and Kitai, countries famous for the cultivation of the cotton plant. It would seem, indeed, from all the passages which occur in ancient authors, concerning the *Seres*, that cotton was the substance alluded to, rather than silk, and that these people were not the present Chinese, but the Tartars of Kitai."

† Herodotus, Lib. iii. 106, when writing of India, mentions trees growing wild, and instead of fruit, bearing a sort of wool, finer and better than that of sheep; and he adds, that the Indians clothed themselves with wool gathered from these trees. Arrian, also, on

the intertropical coasts and islands on that continent. Its introduction to Greece, Malta, Sicily, Apulia, and Spain, was probably effected by the Saracens.

Such quotations might be multiplied, but I have given more than enough of them.

The structure of the fibres of cotton has not been well ascertained. Lewenhoeck, by microscopical examinations, found each of them to have two sharp sides; and it seems to be owing to this circumstance, or to their possessing some asperities like the filaments of wool, that cotton greatly irritates and inflames wounds, ulcers, &c. if applied to them instead of lint, from which they differ totally in this respect; and perhaps the particular structure which occasions this difference, also occasions some in the conformation and number of their pores, to which we may probably ascribe the disposition which cotton manifests, to admit and retain colours better than linen, though not so well as wool and silk, because its vegetable nature does not afford it equal attraction for colouring matters.

M. le Pileur d'Apligny endeavoured to explain the cause, why colours are less durable when dyed in silk, cotton, and linen, that in wool, by supposing that the pores of the three first of these substances, were smaller than those of wool; and that therefore colouring particles could not enter into them so easily and freely as into those of wool. But the very reverse of this supposition seems true, there being little difficulty in making silk, cotton, or linen, imbibe colours, even when topically applied cold, without any artificial dilatation of their pores, which is necessary in the dyeing of wool. The real diffi-

the authority of Nearchus, says, the Indians clothe themselves with linen produced upon trees: and Virgil mentions the

———" Nemora Æthiopum molli canentia lana."

GEORG. ii. v. 120.

culty, therefore, is not in making them imbibe, but in making them retain, the colouring particles when imbibed; because, being admitted so readily, into their undilated pores, they cannot be afterwards compressed, and held therein, by any contraction of these pores, as is done in those of wool. We know that it requires twice as much cochineal, to produce a crimson on silk, as on wool; which is a proof that it can take up a greater quantity, and consequently that its pores are at least sufficiently large, and accessible: we know also, that unbleached cotton is always preferred for dyeing the Turkey red, it being found to retain the colour most permanently; doubtless, because its pores, or interstices are less open before, than after the operation of bleaching. This is also the case of raw or unscoured silk, which, as the ingenious Mr. Henry of Manchester, observes, is "more easily and permanently dyed, than that which has passed the above described process," of whitening and scouring: and, indeed, the openness of the pores of cotton and linen, and their consequent readiness to imbibe, both colouring particles, and the earthy or metallic bases employed to fix most of them, are circumstances upon which the art of calico printing is in a great degree founded. To prepare and dispose cotton for receiving colours by dyeing, it is commonly boiled, in a very diluted solution of vegetable or fossil alkali, for about two hours, and afterwards rinced in clean running water; and for calico printing, it is soaked in water, acidulated with about one-fiftieth of its weight of sulphuric acid, and afterwards rinced thoroughly in a clear stream of water. Cotton bears the action of acids much better than either wool or linen.

Concerning flax, and its conversion to linen, so much has been written, both by ancient and modern authors, and its preparation for dyeing so nearly resembles that of cotton, that I may hope to be excused, for not discussing this subject.

CHAPTER III.

Of the different Kinds and Properties of colouring Matter, employed in Dyeing, Calico Printing, &c.

"Toutes les choses visibles se distinguent ou se rendent desirable par la couleur."
COLBERT. *Instruction general pour la Teinture, &c.*

BY colouring matter, I understand a substance which possesses, or acquires a power of acting upon the rays of light, so as either to absorb them all, and produce the sensation of black; or only to absorb particular rays, and transmit or reflect others, and thereby produce the perception of that particular colour, which belongs to the ray or rays so transmitted or reflected.

Among minerals, the colouring matter of each is commonly distributed equally to all its parts; but in animal and vegetable substances, it generally exists in particular parts, or particles, which are capable of being extracted and collected for the purposes of dyeing, &c.

Colouring matters possess peculiar chemical properties, which distinguish them from all other kinds of matter; for besides their several affinities with particular rays of light, they have others which render them susceptible of being acted upon, and modified by a variety of chemical agents, as well as of forming permanent combinations with the filaments of wool, silk, cotton, linen, &c. But in respect of these affinities, colouring matters also differ essentially from each other, and must therefore be applied in different ways, and with very different means, to produce permanent colours in other matters. The art of dyeing is founded upon a knowledge of the particular properties and affinities of these matters, not only as far as they relate to the substances intended to be dyed, but also as far as they are connected with the operations of other agents, by

which they are liable to be acted upon, either during the process of dyeing, or afterwards.

Many species of animal and vegetable colouring matters, suffer nearly similar changes from the action of acids, alkalies, and other chemical agents; from which it may be presumed, that there is something of a common, or similar nature, in the constitution of many of them. But though it would be highly useful to establish general principles and conclusions on this subject, we are not yet furnished with the necessary facts; and whilst this continues to be the case, it will be best to wait, or rather seek, for more knowledge, and avoid fallacious suppositions or explanations.

Sir Isaac Newton supposed coloured matters to reflect the rays of light; some bodies reflecting the more, others the less refrangible rays most copiously; and this he conceived to be the true, and the only reason of their colours. Mr. Delaval, however, has lately maintained (in the 2d vol. of the memoirs of the Philosophical and Literary Society of Manchester,) " that, in transparent coloured substances, the colouring matter does not reflect any light; and that when, by intercepting the light which was transmitted, it is hindered from passing through substances, they do not vary from their former colour to any other colour, but become entirely black:" and he instances a considerable number of coloured liquors, none of them endued with reflective powers, which, when seen by *transmitted* light, appeared severally in their true colours; but all of them, when seen by *incident* light, appeared black: which is also the case of black cherries, black currants, and blackberries, &c., the juices of which appear red when spread on a white ground, or otherwise viewed by transmitted, instead of incident light; and he concludes, that bleached linen, cotton, &c. " when dyed or painted with vegetable colours, do not differ in their

manner of acting on the rays of light, from natural vegetable bodies; both yielding their colours by transmitting through the transparent coloured matter, the light which is reflected from the white ground:" it being apparent, from different experiments, " that no reflective power resides in any of their component parts, except in their white matter only," and that " transparent coloured substances, placed in situations by which the transmission of light through them is intercepted, exhibit no colour, but become entirely black."

" The art of dyeing, therefore, (according to Mr. Delaval,) consists principally in covering white substances, from which light is strongly reflected, with transparent coloured media, which, according to their several colours, transmit more or less copiously the several rays reflected from the white substances," since " the transparent media themselves reflect no light; and it is evident that if they yielded their colours by reflecting, instead of transmitting the rays, the whiteness, or colour of the ground on which they are applied, would not in any wise alter or affect the colours which they exhibit."

Having had reason to differ from Mr. Delaval on other points, I am happy in being able to agree with him on this, so far as relates to transparent colouring matters, when applied to wool, silk, &c. without the interposition of any earthy or metallic basis. But when any such opake basis is interposed, the reflection is, doubtless, made principally by it, rather than by the substance of the dyed wool, silk, &c., and more especially when such basis consists of the white earth of alum, or the white oxide of tin; which, by their strong reflective powers, greatly augment the lustre of colours. There are, moreover, some opake colouring matters, particularly the acetous, and other solutions of iron,

used to stain linen, cotton, &c., which must necessarily themselves reflect, instead of transmitting the light by which their colours are made perceptible.

It has been already mentioned, that when the rays of light are separated from each other by the prism, in consequence of their different degrees of refrangibility, they produce a perception of seven distinct colours, with all their intermediate shades; and that these are all equally simple and primitive. There is, however, this peculiar property belonging to the red, yellow, and blue colours, whether prismatic or permanent, that they are incapable of being produced, like all the rest, by the *combination* of any other colours. Blue and red will compose a purple; blue and yellow, a green; red and yellow, an orange, &c.; but none of these, by any composition, will produce either the blue, yellow, or red: these last, therefore, are in all cases *simple* or uncompounded;* but all the others may be, and in reality are, sometimes simple, and sometimes compounded; and this is true not only of those which are merely prismatic colours, but of those which exist naturally in bodies, or are communicated by painting, dyeing, &c. Iron, as has been already mentioned, will, by different degrees of oxydation, produce all possible varieties of colour; and these colours will be all simple, or uncompounded; and so will the purple of gold, the green of copper, and the other colours found in the several oxides of metals. This is also the case of the violet and purple dyed from logwood; of the green of the leaves, &c. of vegetables;

* Dufay would only admit of three primitive colours, red, blue, and yellow, because with these dyers and painters can readily compound all the others; and a late writer, adopting Dufay's opinion on this subject, says, the colours of the prism are immaterial, accidental, and artificial. But those of the dyer and painter are substantial, natural, and palpable.

and of the orange dyed from the quercitron bark, as will be hereafter mentioned. And among animal colours, numerous instances may be alleged of simple or uncompounded greens, oranges, purples, and violets: even the yellowish white liquor of the murex, and buccinum, from which the celebrated Tyrian purple was produced, passes quickly through all the shades of yellow, green, violet, and purple, upon being exposed to the sun; and these must necessarily be deemed simple, not compound colours. But on the other hand, dyers, painters, &c. daily produce orange, green, purple, and violet, by mixtures of the blue, yellow, and red: nor is it necessary that these should be intimately mixed, since cloth woven from a red warp, and a blue woof, will appear to be uniformly purple or violet; or if the warp be yellow instead of red, the cloth will appear *green*, in each case exactly resembling the simple homogeneous colour, which, in the prismatic series, lies between the colours of the warp and woof. It has moreover been repeatedly found in dyeing compound colours, as for instance, green, that laying a permanent blue over a fugitive yellow, does not defend the latter, or make it in any degree more lasting, but that it will decay (leaving the blue in full strength) as rapidly as if no blue had been applied; and therefore we may presume, that the fibres of the dyed stuff were but partly covered with the yellow colouring matter, and that when the blue came to be afterwards added, its particles found spaces sufficient to lodge themselves collaterally, without being placed upon the yellow particles.

Several attempts have been made to arrange and class the different species of colouring matters employed for dyeing and calico-printing; but none seems to accord with, or give just ideas of, their several natures and properties. M. Berthollet, indeed, alleges sufficient

reasons for not dividing these matters, as Mr. Macquer did, into extractive and resinous, and also for not making their effects depend, as Mr. Pœrner has done, upon the mucilaginous, earthy, saline, resinous, or oily parts of which they were supposed to be compounded, but without proposing any suitable arrangement of his own.

To me, however, colouring matters seem to fall naturally under two general classes; the first including those matters which, when put into a state of solution, may be fixed with all the permanency of which they are susceptible, and made fully to exhibit their colours in or upon the dyed substance, without the interposition of any earthy or metallic basis; and the second, comprehending all those matters which are incapable of being so fixed, and made to display their proper colours, without the mediation of some such basis. The colours of the first class I shall denominate *substantive;* using the term in the same sense in which it was employed by the great Lord Verulam, as denoting a thing solid by, or depending only upon, itself; and colours of the second class I shall call *adjective*, as implying that their lustre and permanency are acquired by their being adjected upon a suitable basis.

Earthy and metallic bases when thus interposed, serve not only as a bond of union, between the colouring matter, and the dyed substance, but they also *modify* (as well as fix) the colour; some of them, particularly the oxide of tin, and the earth of alum, *exalting* and *giving lustre* to most of the colouring matters, with which they are united; whilst others, and especially the oxide of iron, blacken some, and darken almost all such matters, if made to combine with them.

Substantive colouring matters are but few in number, because a few only of the substances employed in dyeing, possess such decidedly energetic affinities, as to be able

to contract a permanent union with the stuffs to be dyed, merely by being applied to, or brought into contact with them. This is more especially true of *linen* and *cotton;* for in regard to wool, several of the adjective colouring matters, particularly those of Madder, Cochineal, Kermes, and Lac, are so much attracted by it, that with the aid of boiling water they fix themselves in, or to, the fibres of wool, so as to produce colours of some, though less durability, than those which would have been produced if a basis of alumine, or the oxide of tin, had been also applied; and without such basis, these colours never rise so high, or acquire so much lustre, as they would have done therewith.

Of substantive colours, I shall first notice the animal, next the vegetable, and, lastly, the mineral.

CHAPTER IV.

Of Substantive Animal Colours, and principally of the Tyrian Purple.

———"Tyrioque ardebat *murice* lana."—*Virg. Æneid, lib.* iv.

"Huic *fasces secures que Romanæ viam faciunt:* idemque pro *majestate* pueritiæ est: distinguit ab equite Curiam: *Diis advocatur placandis:* omnemque vestem illuminat: *in triumphali miscetur auro:* qua propter excusata et *purpuræ* sit insania."—*Caii Plinii secundi Hist. Lib.* ix. *cap.* 36.

This, during many ages, was the most celebrated, and *venerated* of all the colours given by dyeing; and among the rich and beautiful, it seems to have been the first which mankind were enabled to fix permanently on wool, and linen. It was obtained from a whitish half-fluid matter, secreted by particular organs in certain *univalvular* shell fish, and retained in an appropriated receptacle, with which they were each naturally provided; though we are completely ignorant of any benefit which this secretion produced to the fish themselves.

There is much obscurity, and some inconsistency, in the accounts transmitted by ancient writers of the shell fish, which afforded the purple dye. Those of Pliny are the most copious and intelligible, though they are sometimes at variance with each other. He mentions these fish under the several names of Conchylium, Murex, Purpura, and Buccinum; and these several names have been also employed by other Latin authors. But Fabius Columna, a noble Neapolitan, who first published figures of plants, from engravings made by his own hand, and wrote a learned dissertation *de purpura*, (printed at Rome in 1616) after much pains employed, to elucidate and reconcile the different passages of ancient writers on this subject, thinks himself warranted to conclude that there were but two kinds or genera of these fish, viz. the purpura and the buccinum: that the

term *conchylium*, signified generally all the species of purpuræ, and that it was also used sometimes to signify the purple colour itself; that Pliny employed it in the former sense, in the 41st chapter of his 9th book, and in the latter, in the 86th chapter of the same book; that the term murex, was also used as a generic name for the purpuræ; and consequently that both conchylium, and murex, were synonymous, of the purpura; "quarum alterum a conchis nomen, alterum ab aculeis, qui alio nomine murices dicuntur." I am afraid, however, that Pliny was neither constant nor correct in using these names, even in the ways by which Columna endeavours to render him consistent and intelligible: for in the chapter last quoted, he mentions the purpuræ, and the murices, as being different fish, and compares their respective habits, &c., adding as a peculiarity of the former, "Sed purpuræ florem illum tingendis expetitum vestibus, in mediis habent faucibus: liquoris hic minimi est *in candida vena*, unde pretiosus ille bibitur nigricantis rosæ colore sublucens." It seems probable that the term murex,* was in this instance erroneously substituted for buccinum; as he proceeds to state that all the shell fish yielding the purple, or other lighter colours of the conchylia, are *in matter the same*, and differing only in temperament; that they are of two kinds, ("duo sunt genera") one which is the lesser kind, being called *buccinum*, from its likeness to the horn or cornet, so named and employed to produce sound by blowing through it ("quo sonus editur.") These last he describes as being round at the aperture, with a serrated margin. The other kind, says he, is

* "Murex cochlea est maris, dicta ab acumine et asperitate quæ alio nomine conchylium nominatur, propter quod circumcisa ferro, lacrymas coloris purpurei emittat, ex quibus purpura tingitur, inde ostrum appellatum," &c.—Isidorus, lib. 2. Origin. cap. 6.

called *purpura*, and has a projecting pipe-shaped beak (rostrum) with a lateral winding cavity, through which it puts forth its tongue; the body of the shell is moreover muricated, or armed, even to its upper pointed extremity, with rows of spines, seven in number; which are wanting in the buccinum. This last, he adds, adheres to rocks and large stones, whence it can alone be collected.

In the same chapter, Pliny tells us, that the best purpuræ found in Asia, were those taken in the sea adjoining to Tyre: that in Africa the most esteemed were those of Meninx (Meninge,) and the sea coast of Getulia: and in Europe those of Laconica. He adds that the Tyrians, when they caught any of the greater purpuræ, took the fish out of their shells, the better to extract the colouring matter, but that they obtained it from the smaller by grinding them in mills. That the fishermen endeavoured to take the purple fish alive, because it otherwise ejected and lost its precious liquor, together with its life. But on this point he seems to have been misinformed, there being good reason to believe that this fish never ejects the liquor in question.* He adds, moreover, that this fish dies speedily, if put into fresh water, but that it will otherwise live upon its own saliva, fifty days after being taken.

In the next chapter, Pliny tells us, that the purpuræ were also called *pelagiæ*, (probably from their inhabiting the ocean) and that there were several varieties of them, named differently from the places where they were found, and the food on which they subsisted; and

* This is, at least, true of buccinum, whose colouring matter I found unaltered some days after the fish, or limax had died slowly, by being kept seven or eight weeks without water, and it was not until putrefaction had made a *sensible* progress, that the colouring matter became incapable of producing its proper effect.

he afterwards describes the manner in which they were caught. In his 38th chapter, he states, that when the purpuræ were caught, the white vein or receptacle, before described, was taken out, and laid in salt for three days, after which a sufficient quantity of the matter so extracted and salted, was boiled slowly in leaden vessels, over a gentle fire, the workmen from time to time skimming off the fleshy impurities: this process lasted ten days, after which the liquor was tried by dipping wool into it, and if the colour produced by it was defective, the boiling was renewed. Pliny afterwards erroneously represents the liquor of the buccinum as only yielding a fugitive colour; and says it was commonly mixed with more than half as much of the liquor of the pelagium, which of itself gave a very dark purple; and that being so mixed these liquors improved each other, the latter giving permanency to the former, and being in return brightened and enlivened by it; and thus producing a most beautiful amethyst colour. ("Amethysti color eximius ille.") He adds, that the Tyrians produced their purple, by first dyeing the wool with the unprepared or *greenish* liquor of the pelagium, and afterwards in the liquor of the buccinum, and that this colour was deemed most perfect, when it resembled the colour of coagulated blood, &c. "Laus ei summa color sanguinis concreti, *nigricans aspectu*, idemque *suspectu refulgens:* unde et homerus purpureus dicitur sanguis."

In his forty-first chapter, Pliny farther tells us, that it not being thought sufficient to transfer the colour of the amethyst to wool, it had become the practice to dye the latter again, with the Tyrian purple, that it might obtain a compound name (Tyriamethystus,) corresponding with this double luxury: and that being saturated with colour of the conchylium, it was deemed

fitter to receive the Tyrian dye. He adds, that not content with thus combining colours obtained from the ocean, recourse was also had to those produced on the land; and that wool, or cloth, dyed crimson, from the coccus (kermes,) was afterwards made to imbibe the Tyrian purple, in order that it might assume the colour which was named *hysginus*, after a flower so called; this colour partook greatly of the crimson tint. But besides the coccus (kermes,) other colouring matters were employed, sometimes to economize, and at others to vary the effects of the liquors of the purpura and buccinum; and more especially that of the lichen roccella, or archil, which Pliny mentions under the name of *fucus marinus*, and which, even at this time, is greatly employed in dyeing, though its beautiful purple colour fades rapidly. Indeed, this lichen, or moss, was in such general use as a dye, at and before the time when Pliny wrote, that its name *fucus* came at length to signify generally, colours given by dyeing; of this, among numerous other instances, may be quoted the following line, by Catullus (de Nuptiis Pelei et Tetidos,) viz.

> "Tincta tegit roseo conchylis purpura fuco."

Of this fucus, that from Crete was the most esteemed.

Pliny tells us also, Lib. xxii. cap. 17, that the alkanet root, (anchusa tinctoria) was likewise employed as a ground for the purple dye.

By these and other means, the purple colour was made to assume a variety of shades, some inclining more to the blue, and others more to the crimson. The principal of these varieties were noticed by Pliny, in the eighth chapter of his twenty-first book, when, after mentioning the luxurious art by which men had surpassed the savour of *natural flowers*, by artificial odours, he adds, that they had also learned by dyeing, to emu-

late the finest colours of these flowers; and that of these beautiful dyes there were three divisions; one in which the coccus (kermes) was employed, and which equalled the brightest colour of the rose, (" qui in rosis micat;") and here he observes, that nothing could be more grateful to the sight, than the Tyrian and Laconican purples, especially when *twice dyed* (dibaphasque."*) In the second division he mentions the *amethyst*, inclining to the violet; and also the purple called janthinus.† His third division includes the colour strictly called conchylium, of *various tints;*‡ one resembling the heliotrope or turnsole, of which, says he, there are several shades; another approaching the mallow, with a mixture of purple, and a third, resembling the later violet, (" viola serotina," probably the purple stock gilly-flower:) this he mentions, as being the richest colour that could be obtained from the purple shell fish: and thus, says he, nature and art striving against each

* Horace alludes to this twice dyed purple, (purpura di bapha) in the following lines.

> " Te *bis* afro murice tinctæ vestiunt lanæ"—and
> " Muricibus tyriis *iteratæ* vellera lanæ."

† The amethyst purple was lighter, and partook more of the blue tint than the dark Tyrian dibapha: that variety of it called janthinus was so named from ja, a species of violet.

‡ Lucretius de rer. nat. l. vi. says of this colour:

> " Purpureusque color conchyli jungitur una,
> Corpore cum lana."

It was lighter and had less body than the Tyrian purple, being dyed with half the quantity of the liquor of the purpura; it also inclined more to the blue, whence it frequently acquired the names of hyacinthus, and cæruleus; and, from its having less body, those of color dilutus, and ablutus; which last word by abbreviation is supposed to have produced that of *blutus;* whence the French *bleu*, the English *blue*, and the German *blau*. Braun says this colour is called *thechelet* in the Hebrew Bible, and the shell fish producing *it* chilzon. Braun de vests. Sacerd. Hebræor. i. 12.

other, maintain an equal conflict. "Paria nunc componuntur, et natura atque luxuria depugnant."

Various (and probably fabulous) accounts of the first discovery of this purple, have been related by different writers. One of these ascribes it to a dog, who, when following the nymph Tyros, and a certain Hercules her lover, along the sea shore, caught one of the purpuræ lying on the sand, and breaking the shell with his teeth, his mouth became coloured with the purple juice, which the nymph observing, expressed a strong desire to obtain a dress dyed of this colour. And the lover anxious to satisfy her desire, discovered by a proper examination, how this beautiful purple might be obtained, and communicated by dyeing.* And the nymph, by whom the purple so discovered was first worn, being named Tyros, the colour is supposed to have thence obtained the appellation of Tyrian purple. Others have related, that this discovery was made by the Phœnician Hercules,† and afterwards communicated it to the king of

* See Cassiodorus, lib. i. and Julius Pollux, lib. i. 4.; from the latter, Polydore Virgil has taken the story.

† Sir Christopher Hawkins, in his "Observations on the tin trade in Cornwall," (lately published) mentions this Hercules, as one said to have been the greatest Phœnician navigator, "and the first who brought tin from the Cassiterides, or British isles:" and, adverting to the story of his having also "invented the *shell purple*, by accidentally remarking that a dog's mouth was stained therewith," he observes, that "as both these discoveries are attributed to the same person, we may thence infer, that the tin of Britain was *an essential* ingredient in fixing the fine purple dyes of the ancients; or, (adds Sir Christopher,) as Mr. Polwhele elegantly expresses it, "very possibly the purple dye of the Tyrians, gained its high reputation among the ancients, from the use of our tin, in the composition of the dye stuff, as the tin trade was solely in their own management." On this subject, however, Sir Christopher, perhaps, from a partiality in him, both natural and excusable, towards Cornwall, has departed from his usual logical accuracy, and

Phœnicia, who thereupon, immediately began to wear purple. (See Goguet, l. ii. ch. 2.) That this colour first became known at the city of Tyre, and thence obtained its name, is rendered probable by the fact, of its having also borne the appellation of *Sarranus*, from *Sarra*, the name by which that city had been previously distin-

hazarded an inference which his premises do not warrant; for though it were true, that tin was first carried to Tyre, and the shell purple first discovered there, by *the same person;* we should have no right to conclude that the former was necessarily employed to produce the latter; and there is not only no evidence that this ever *was*, but on the contrary, many facts prove that it never could *have been* the case; indeed, my own experiments will show, that the colourable matter of the buccinum attains its beautiful purple, and fixes itself permanently, without any *other aid* than that of solar light, and also that solutions of tin are completely useless for either of these purposes: nor is there the smallest reason to suspect that they ever were employed for dyeing, until the seventeenth century.

In another paragraph, which Sir Christopher has subsequently quoted from Mr. Polwhele, the latter supposes, that the Phœnicians must have known the use of tin, "as one of the non-colouring retentive ingredients;" because, "it is not likely that *the simple blood of the shell fish, however beautiful at first, could have proved a lasting dye;*" and, therefore, he imagines, that "some retentive ingredients," (like "tin dissolved in aqua fortis,") "must have been necessary to secure its *brightness*, and preserve its beauty."—The "*brightness* and *beauty* of the "*simple blood of a shell fish!!*" Of the "*purpura*," and the buccinum!!! As well might Mr. Polewhele expatiate on the brightness and beauty of the simple blood of the *oyster* and the *snail;* and suppose that by the help of tin, they would produce the Tyrian purple. How an idea so extravagant, and so indicative of gross inattention to the common productions of nature, could have occurred to this gentleman, I know not, unless he derived it from the following lines of Martial, viz.

"*Sanguine* de nostro tinctas, Ingrate, lacernas
Induis; et non est hoc satis: esca sumus."

guished; and, hence the following line of Virgil, (2 Georg. 506.)

"Ut gemma bibat, et *Sarrano* dormiat *Ostro*."

Respecting the time when this discovery was first made, the more ancient writers do not agree, some stating it to have been about 1500 years previous to the Christian æra, and others almost a century later, whilst Minos reigned in Crete.

Pliny appears to think, that purple had been worn at Rome, soon after the building of that city, but that even Romulus never wore it, except in his *trabea*, or *regal mantle:* and he states, as a certain fact, that Tullus Hostilius was the first king of Rome, who assumed the *pretexta* or long robe, with *broad* purple stripes, after having subdued the Tuscans. He adds, "Nepos Cornelius, who died in the reign of Augustus Cæsar, when I was a young man, assured me that the light voilet purple had been formerly in great request, and that a pound of it was commonly sold for 100 denaria, (nearly 4*l.* sterling:) that soon after the *tarentine* or reddish purple came into fashion; and that this was followed by the Tyrian dibapha, which could not be bought for less than 1000 denaria, (almost 40*l.* sterling) the pound; which was its price when P. Lentulus Spinter was Ædile, Cicero being then Consul. But after this, the double-dyed purple became less rare, &c." See lib. ix. c. 39.

As soon as mankind were acquainted with the purple as a dye, they seem to have considered it, not only as being of all others the most estimable in itself, but also the most acceptable to the gods. It was, therefore, naturally appropriated to the services of religion, and of its ministers, as well as to distinguish the highest civil and military dignities. Pliny has noticed the use made of it by Romulus, and succeeding kings of Rome, as well as afterwards by

the consuls, and higher magistrates of the republic. Under the Roman Emperors, it became the peculiar emblem, or symbol of majesty, and the wearing of it by any who were not of the Imperial family, was deemed a *treasonable usurpation*, punishable by death; as was mentioned by Suetonius. (Vita Neronis.) Hence the expressions of "sacer murex," and of "*adorare purpuram*," in the Roman laws. (See Bischoff Versuche, &c.)

When so much importance and *sanctity* (if I may use this expression,) had been attached to this colour, the dyeing of it was confined to a few particular places, and also to a few persons called *muricilegulі;* and we need not therefore wonder, that after the Greek empire had been overthrown, the knowledge of the shell-fish affording the purple colour, as well as the ways of employing them as a dye, should have been completely lost in the 12th century; and that afterwards, when learning began to revive, some persons should have doubted, whether either of these had ever existed; nor need we wonder, after this loss, that the high pre-eminence which had belonged to the purple, was in a considerable degree transferred to the scarlet, afforded by the kermes; which after being called *red purple*, at length obtained the name (unknown to the ancients) of *scarlet*,* as we learn among others from Caneparius, who in his work *de Atramentis*, p. 207, after mentioning that the ancient purple *then unknown*, had formerly distinguished emperors, kings, &c. adds, "Nostra autem ætate (the beginning of the 17th century) hujuscemodi vestes vocantur *scarlati*, quibus *Venetiis* illustrissimi, Senatores procedere conspiciuntur."—Again, in the next page he says, "Quamobrem ubique, et Venetiis præsertim

* This colour afterwards obtained the name of *Venetian scarlet*, to distinguish it from the *brighter* colour, now called scarlet, and which had never been seen until Cochineal, and the effect of solutions of tin upon its colouring matter, were discovered, about the year 1630.

maxime existimatur purpura, vulgari dictione, dicta *escarlatum*, pro illustrissimis patriciis insigniendis." He mentions also that the violet purple was then commonly called "*el Pavonazzo*," by the Italians. It was probably then dyed from archil only.

It happened, however, more than sixty years after the work of Canniparius had been printed at Venice, that Mr. William Cole, of Bristol, being at Minehead (viz. in 1683,) he was there told, of a person living at a seaport in Ireland, "who made considerable gain by marking, with a delicate durable crimson colour, the fine linen of ladies and gentlemen, sent to him for that purpose;" and that this colour was "made by some liquid substance, taken out of a shell-fish." Mr. Cole being a lover of natural history, and having his curiosity thus excited, went in quest of these shell-fish; and after trying various kinds without success, he at length found considerable quantities of a species of buccinum on the sea-coasts of Somersetshire, and the opposite coasts of South Wales; and after many ineffectual endeavours, he discovered the colouring matter placed in a "white vein, lying transversely in a little furrow, or cleft, next to the head of the fish;" which says he, "must be digged out with the stiff point of a horse-hair pencil, made short and tapering, by reason of the viscous clamminess of the white liquor in the vein, that so by its stiffness it may drive in the matter into the fine linen, or white silk," intended to be marked. Letters or marks made in this way, with the white liquor in question, "will presently," adds he, "appear of a pleasant green colour, and if placed in the sun, will change into the following colours, *i. e.* if in the winter, about noon, if in the summer, an hour or two after sun-rise, and so much before setting (for in the heat of the day in summer the colours will come on so fast, that the succession of each colour will scarce be distin-

guishable;) next to the first light green, will appear a deep green;" "and in a few minutes this will change into a full sea green; after which, in a few minutes more, it will alter into a watchet blue; from that, in a little time more, it will be of a purplish red; after which, lying an hour or two (supposing the sun still shining,) it will be of a very deep purple red; beyond which the sun can do no more." He remarks, however, "that these changes are made faster or slower, according to the degree of the sun's heat;" "but then," adds he, "the last and most beautiful colour, after washing in scalding water and soap, will (the matter being again put out into the sun or wind to dry) be much a differing colour from all those mentioned, *i. e.* a fair bright crimson, or near to the Prince's colour; which afterwards, notwithstanding there is no styptic to bind the colour, will continue the same, if well ordered, as I have found in handkerchiefs that have been washed more than forty times; only it will be somewhat allayed from what it was, after the first washing." Mr. Cole found, that, if linens marked with the white liquor in question were taken out of the sun, when the colours had only reached any one of the before mentioned shades, and shut up between the leaves of a book, the colour or colours made no farther progress whilst so shut up, but remained always of the same shade. He also found, that whilst linen marked with the white liquor was drying by exposure to the sun, *for the first time*, it would always "yield a very strong fœtid smell (which divers who smelt it could not endure,) as if garlick and assafœtida were mixed together;" and this happens in cases where linen, after being marked, had been shut up in a book for twelve months, before it was exposed to the sun's rays. He also found, that the colour in linen which had been dried, and washed immediately after being marked, was better than when it had lain fourteen months between the leaves of a book, unwashed.

Mr. Cole sent some of the first linen marked by him in this way, to Dr. Plot, then one of the Secretaries of the Royal Society, in November, 1684; and it was soon after shown to king Charles the Second, who admired it greatly, and desired that some of the shell-fish might be collected and brought to town, that he might see the liquor applied, and the successive changes of colour which it underwent; but before this could be done, the king died; and though Mr. Cole's letter (from which the preceding extracts were made) was in the following year published, in the fifteenth volume of the Philosophical Transactions, and excited the attention of philosophers in most of the countries of Europe, it does not appear that any attempt was made to revive the practice, along with the knowledge, of dyeing the ancient purple.

After an interval of twenty-four years, M. Jussieu found a small species of buccinum, in form resembling the garden snail, on that part of the French coast which is washed by the Atlantic ocean, and presented some of them, in the year 1709, to the Royal Academy of Sciences at Paris; and in the following year, the celebrated M. Reaumur found great quantities of the buccinum on the coast of Poitou; and he morever observed, that the stones, and little sandy ridges round which these shell-fish had collected, were covered with a kind of oval "graines," some of which were white, and others of a yellowish colour; and having collected and squeezed some of these upon the sleeve of his shirt, so as to wet it with the fluid or liquor which they contained, he was agreeably surprised, in about half an hour, upon finding it stained of a fine purple colour, which he was unable to discharge by washing. This was done upon the sea-shore. He next collected a quantity of these grains, and carrying them to his apartment, bruised and squeezed different parcels of them upon bits of linen; but to his

great surprise, after waiting two or three hours, no colour appeared upon the spots wetted with their liquor. Unable to conceive the reason of this disappointment, and having almost determined to return again to the sea-shore, and repeat his experiment in the same place as before, he chanced to perceive some purple spots, occasioned by drops of the liquor which had accidentally fallen upon a part of the plaster of Paris with which the sides of the window were covered, and which, having been more strongly acted upon by the light, than the bits of linen wetted with the same liquor in the interior part of the room, had become purple, though the day was then cloudy. Without, however, perceiving this to have been the cause of his disappointment, he broke off a bit of the same plaster, and carrying it to the back part of the room, where the bits of linen in question were laying, he wetted it with the same liquor, without its becoming coloured. He then thought of carrying the colourless bits of linen to the window, which was open, and there he soon perceived them to become purple. It was then fashionable to explain all effects upon mechanical principles, as it had been at the time when he also endeavoured to account for the shock of the torpedo, as resulting *mechanically* from a very quick stroke given by the contraction of particular muscles in that fish. M. Reaumur, therefore, soon persuaded himself, and others, that the bits of linen which had remained colourless whilst at the back part of his room, were rendered purple at the window by the different manner in which the air acted upon the colouring liquor in the latter; and that this difference consisted solely in the air's having greater motion at the window, than at a distance from it; and almost all his subsequent experiments, seem to have been calculated to confirm this erroneous hypothesis.

He placed bits of linen, just wetted with the colouring

liquor, in the open air, and laying a stone upon each, he found the covered part remain colourless, whilst the rest were made purple; which he ascribed to the mechanical impression of wind, not considering that the stones kept off the light, as well as the air.—Having read an account of Mr. Cole's observations, in the Philosophical Transactions, M. Reaumur exposed a bit of linen, wetted with the colouring liquor, to the rays of the sun, collected by a small burning glass, and saw it become purple in an instant; and consequently, without being able to distinguish any of the changes of colour through which it had so rapidly passed. Putting another bit of linen, wetted with the same liquor, so near to the fire that it would have burned had it been dry, he likewise saw it become purple immediately; but with equal degrees of heat, the effects produced by the sun's rays were beyond comparison the greatest.

M. Reaumur conceived the grains in question to be the eggs or spawn of some fish, but whether of the buccinum, or any other species, he was uncertain; and under this uncertainty he proposed calling them "Oeufs de pourpre," eggs of purple. The colour which they produced, was at least equal, if not superior in beauty, as well as durability, to that of the buccinum; though the colouring liquor of the latter was much thicker than that of the purple eggs, and not liable to pass through the different changes of colours so quickly as that of the eggs, excepting when diluted. Having put some of this diluted liquor into two glasses, and placed one of them in contact with the sun's rays, and the other near the fire, the former became purple without any sensible addition of heat, whilst that which was at the fire had only began to acquire the first shade of colour, though it was sensibly hot: and indeed he always found the colours produced by the sun to be more beautiful than any others; a circumstance

which he endeavours to explain, by supposing its rays to act mechanically, in changing the figures or arrangements of the particles of the liquor, in the same way as he supposed the wind to change them, but with more efficacy.

M. Reaumur perceived the same disagreeable smell of garlick from the liquor, which Mr. Cole had before mentioned; and he found it the more insupportable, as the heat of the sun or fire was the strongest. The colour of the liquor was not produced, or affected either by vegetable alkali (carbonate of potash), or sulphuric acid; but a very little corrosive sublimate of mercury, put into the diluted liquor of the buccinum, instantly rendered it blue, and the colour was soon precipitated with the mercury, to the bottom of the vessel, leaving the liquor colourless; an effect which, as usual, he endeavoured to explain mechanically, by supposing the sublimate to consist of little globules stuck round with sharp points, which enabled it to change the arrangement of the particles of the liquor more expeditiously, even than he had supposed it done by the wind. He found that the liquor of the buccinum tasted as hot as the hottest pepper, whilst that of the purple eggs was saltish; but even this was so viscid, that it did not run, when topically applied to linen, &c.; and as the eggs were, according to M. Reaumur's account,* so plentiful, that one man might collect half a bushel of them in a few hours, there certainly is reason to think, that they would be highly useful, at least in calico printing, where their liquor might be applied, with the greatest facility, both for penciling and printing, as a substantive topical colour, and where a small quantity would go far, especially upon fine muslins. But at that time the art of calico printing had not been practised in France, and

* In the Mem. de l'Acad. Royale des Sciences, &c. an. 1711.

therefore nobody thought of applying M. Reaumur's discoveries in that way.

About the beginning of the year 1736, M. Duhamel found the *purpura*, (the buccinum only having been discovered by Cole and Reaumur,) in great abundance upon the coast of Provence; and observed it to agree very well with the description thereof, given by Rondelet. He found the viscid colouring liquor of the fish to be white, except in a few instances, where it was green, which he suspected to be some morbid effect. The white liquor being exposed to the sun's rays, assumed the following colours; 1. a pale yellowish green; 2. an emerald green; 3. a dark bluish green; 4. a blue, with a beginning redness; and 5. a purple; and these changes all happened in less than five minutes. Linen wetted with the white liquor, and left all night in a dark room, had only become green in the morning; and this was also the case of linen wetted in like manner, and exposed all night in the open air, but shaded from the moon's light. A piece of linen, wetted in the same manner, being partly exposed to the sun's rays, and partly hid by a crown-piece of silver, the former part became purple, whilst the latter was only green. Other linen so wetted, being heated in a Dutch oven before the fire, or upon a hot iron, became of a dark green, but not purple. The fumes of burning sulphur only produced a dark green; and this was moreover the case with the different coloured rays of the sun, applied separately by a prism. Wishing to see whether evaporation tended to colour the white liquor, Mr. Duhamel put some of it into a phial well stopped; and, upon exposing it to the sun, found the liquor become of a reddish purple almost immediately. A piece of linen wetted and stuck upon the back of a plate of polished glass, three lines in thickness, and exposed to the sun's rays, became purple even before it had dried. Three pieces of linen so wetted, being covered, one with white,

a second with black, and the third with oiled paper, the last soon became of a good purple colour, but the others only became green. Linens wetted in like manner, and exposed to the light of the moon, or of burning wood or candles, became green, but not purple. Exposure to the sun's rays always produced the purple, and most expeditiously, when its light and heat were strongest, the sun-shine of the month of March having proved much more efficacious than that of January or February. The purple was instantly produced by the sun's rays, collected under a burning glass. The liquor which M. Duhamel suspected to be morbidly green, became purple sooner than the white liquor; a circumstance which does not indicate its greenness to have been the effect of disease. In linens where the colour had stopped at the green, without reaching the purple hue, it was soon carried off by boiling with soap, fossil alkali, alum, &c. which the colours that had already become purple, withstood for a long time, and were not hurt by the fumes of burning sulphur. See Memoirs of the Royal Academy of Sciences, &c. 1736.

Until Mr. Cole had discovered the buccinum, no adequate conceptions could have been formed of the changes, through which its liquor, and that of the purpura, became purple. Aristotle and Pliny had, indeed, both given intimations of its being primitively white; and Pliny had slightly mentioned one of the intermediate colours, the green.* That the other changes were not more distinctly noticed, must be ascribed to the little attention then bestowed upon subjects of natural philosophy, and perhaps to a want of sufficient communication with the purpurarii piscatories, by whom the liquor was collected and salted. And there can be no doubt of the identity of the shell-fish

* "Color austerus in Glauco, et irascenti similis mari." Lib. ix cap. 36.

employed by the ancients, and those discovered by Cole, Reaumur, and Duhamel, or of the similitude of their changes, and of the means by which their several liquors became purple. In a collection of Anecdota Græca, lately published by M. d'Anse de Villoison, from MSS. preserved in the King's library at Paris, and that of St. Mark, at Venice, there is a description of the manner of catching the shell-fish, employed for the purple dye, written by an eye-witness, Eudocia Macrembolitissa, daughter of the emperor Constantine the eighth, who lived in the eleventh century, while the knowledge and practice of dyeing that colour for the use, and at the expense, of the Greek emperors still subsisted; and from which it manifestly appears, that in those times, as well as in ours, the purple did not acquire its due lustre and perfection until it had been exposed to the sun's rays.

Those who are duly acquainted with the more recent chemical discoveries, can only hesitate between two ways of accounting for the changes through which the liquors of the purpura and buccinum become purple; I mean, whether it be by gaining oxygene from the atmosphere, like indigo, when it acquires its blue colour; or by the separation of a redundant portion of oxygene, naturally combined for some unknown purpose, in the liquor of these shell-fish; and in that particular state which will not admit of its being separated without the application and assistance of light; as is also the case of horned silver, rendered purple by the sun's rays; of vegetables, rendered green by the same cause, after they had become white by growing in darkness; of peaches, purple grapes, and other fruit, which never acquire their proper colours by any degrees of heat, but always remain white or green, if shaded and secluded from the contact of the sun's rays. A very few experiments, which I hope to have an opportunity of

making hereafter, would ascertain this point beyond the possibility of doubt; though in fact there is, I think, at present, very little room to doubt but that the purple, under consideration, is produced in the last of the two ways just mentioned.*

Such were the conclusions which I had formed and published in 1794; and it will soon be found that they have since been completely verified, by the most decisive experiments.

In the month of September, 1803, Mr. Samuel Richardson, of Cowbridge, in Glamorganshire, at the request of my truly respectable friend Dr. Cheston, of Gloucester, obligingly procured and forwarded to me a large parcel of shell-fish, (apparently of that species with which the experiments of Mr. Cole had been formerly made,) belonging to the genus of Buccinum (commonly called whelks) and agreeing in their specific character, with the *buccinum lapillus* of Linnæus.

I had no difficulty in finding and extracting the colouring matter of these Testacca, which in appearance and consistence very much resembled well-formed pus, and was collected to the amount of two or three drops in a little whitish *cyst*, placed transversely under, but in immediate contact with the shell, and near the head of its inhabitant the limax. The white slightly yellowish colour of this cyst, and of the matter contained therein, rendered it perceptible by close inspection through the semi-transparent substance of the shell, though the latter was not furrowed or channelled, where the cyst came in contact with it, as I had supposed from Mr. Cole's description.

* M. Berthollet on the contrary appears to believe that the effect in question, is produced by a farther combination of oxygene. See Elements, &c. tom. i. p. 144, last edition.

This pus-like matter, either diluted with an equal portion of water, or undiluted, being applied to bits of white linen or calico, became purple after going regularly through the intermediate colours mentioned by Mr. Cole, and in the same order. And these changes were completed in a very few minutes, when the sky was serene, and the bits of linen or calico were, *in summer*, fully exposed to the sun's beams; and more especially with the diluted matter; for the undiluted, being often *confined with too much body*, in a small space, was not so soon thoroughly penetrated and changed by the solar rays.

I mixed different parcels of this matter with each of the several alkalies, both in their mild and caustic states, and having applied them to linen and calico, I found that instead of *retarding* the progress of these changes, and the ultimate effect of a *purple* colour, they rather produced an acceleration thereof: and this was the case in a more remarkable degree, when the matter in question was mixed with alcohol, or the volatile essential oils of cajeput, turpentine, lavender, &c. or with *muriatic acid:* on the contrary, these changes appeared to be considerably retarded, by the admixture of nitric acid, though it did not hinder them from ultimately taking place. Sulphuric acid had a similar effect, but in a lesser degree, as had the citric, and acetous acids, and that of tartar. The same matter applied to muslin, and put into a glass filled with hydrogene gas, and closely stopped, being exposed to the direct rays of the sun, went through all the before-mentioned changes in one third less time than usual; whilst similar matter, confined in the same manner with oxygene gas, and exposed at the same time, underwent these changes more slowly: and nitrogene gas employed in the same way, and at the same time, had no apparent influence upon

them. These, and other experiments rendered it at least *highly probable* that *a separation* and not *an addition* of oxygene accompanied and contributed to the attainment of the purple colour in question. But before I had made all the experiments which seemed necessary to ascertain the fact, my attention was unavoidably diverted to other objects; and fearing that my whelks might die, and become unfit for other experiments before I could find leisure to make those which I had projected, I broke the shells of at least one hundred of them, and after extracting their colouring matter, and applying it undiluted to bits of calico and muslin, I placed these bits separately, and as expeditiously as possible, each between two leaves of a large blank folio book, and afterwards kept it *closely shut*, to exclude the light: believing, though the matter in question had not been allowed to become dry before it was shut up in this way, that so much of its moisture would be absorbed by the paper, as to obviate any putrefactive process, and that if this could be obviated, the matter in question would continue fit for my experiments, so long as it should be kept secluded from light. And in these respects my belief appears to have been well founded, since even now (August, 1812,) when almost nine years have elapsed, I find that the bits of muslin so shut up, (of which a score are still remaining) exhibit only the yellowish spots given by this matter as when first applied to them, and that they are as capable as ever, of passing through the usual changes of colour, and finally becoming purple, if assisted by the sun's rays. They do this indeed more slowly, when exposed without being *first moistened;* but after being dipped in water, the changes succeed as regularly, and quickly, as they have usually done with matter just taken from its natural receptacle, and the experiments which I am

now about to relate, were all made with the matter which had been so applied, either to muslin or calico, and secluded from light, more than seven years.

1st. A bit of calico, so impregnated and secluded from light, was put into a very small white glass phial, and the latter being filled with strong nitric acid, which had been diluted by about five times as much water, it was stopped and exposed to the rays of the summer's sun: and in about *twice* the usual time, as nearly as I could judge, the yellow spots became first greenish; then of an apple green, and afterwards of a deep grass green colour: but here the progress appeared to stop so long, that I began to think it would proceed no farther: at length, however, a blue tinge became evident, then a deep blue, and finally a purple; so that the oxygene of the nitric acid, though it manifestly retarded the usual changes, did not hinder their ultimate accomplishment. This experiment was repeated, with a substitution, first of diluted sulphuric, and then of citric acids, instead of the nitric; and with a similar *obstruction* to the usual changes, though it was of less duration; this also happened with the acid of tartar. A similar experiment being made with *undiluted muriatic* acid, the several changes terminating in a *fine purple*, were all completed, and, as I thought, in little more than half the usual time.

This experiment was repeated with bits of impregnated muslin, by substituting caustic solutions of potash, soda, and ammonia separately, for the acids before mentioned; and in all of them, the purple colour was produced, after the usual changes, in full perfection, and, as I thought, with greater celerity than they had formerly been with the matter just extracted from the buccinum; and this also happened with muslin immersed in olive-oil.

A similar bit of muslin put into a phial completely filled with a solution of tin, in muriatic acid, which had been recently made, and was at the minimum of oxidation (if not destitute of oxygene) upon being exposed to the sun's rays, became purple with great celerity, after passing through the usual succession of colours: and this was the case with another bit put into a phial and filled with the oxymuriatic acid (chlorine of Davy) as concentrated as any which I could procure. This last result appeared to me the more extraordinary, because I had previously seen this acid exert its destructive influence upon the purple of the buccinum produced in other ways, almost as quickly and efficaciously, as it is known to do upon colouring matters generally: and I therefore prolonged this experiment, by removing the phial, when the purple was completely formed, to a situation where the *direct* rays of the sun could not reach it; and there I found, after a few hours, that the very same acid which appeared to have accelerated the production of this purple, had afterwards annihilated the colour so produced, leaving the muslin perfectly white!

That I may not unnecessarily prolong this account of my experiments, I will omit several of lesser importance, and proceed to a recital of *two*, which I think conclusive, in regard to the *problematical* part of this inquiry, viz.

First,—into a flint glass phial, more than half filled with quicksilver, (strained through leather,) I conveyed a triangular bit of fine muslin, impregnated, dried, &c. as before mentioned; and having *attached* one corner thereof, by compressing it between the glass stopper, and the opposite inner surface of the mouth of the phial, I inverted the latter, so that the quicksilver sunk down to its neck, pushing the muslin (which by this

attachment was hindered from ascending, and which had been previously spread,) closely upon one side of the inner surface of the phial, the other surface being in immediate contact with the quicksilver, which rose an inch above the muslin; so that the latter was completely secured from the access of atmospheric air; that which the phial contained, being forced by the superior weight of the mercury into the space above it. Thus circumstanced, the phial (in the month of August,) was exposed to the sun's rays, that side of it, upon the inner surface of which the muslin was applied, being turned *towards them:* and in this situation I observed the muslin, or rather the colouring matter of the buccinum, to pass through all the shades of green and blue, and become a full reddish purple with as much celerity, as similar matter in a dried state, had commonly done, when exposed to the sun's beams, with the free access of atmospheric air.

Though it appeared difficult to devise any experiment more decisive than this, I made a second, by filling with quicksilver, a small cylindrical glass tube, 34 inches long, and closed at one end; and having stopped the orifice with my finger, I inverted the glass upon a china cup, containing more quicksilver, and then, withdrawing my finger, the mercury sunk, and left a vacuum above it, of about four inches in height: I then placed a bit of fine muslin impregnated, dried, &c. as before mentioned, under and immediately *before* the orifice of the tube, through which it ascended with great rapidity into the vacant space, and being then exposed to the sun's rays, the usual changes, terminating in a purple colour, *all took place*, as in the preceding experiment, and with equal celerity.

In the first of these latter experiments, there was no vacuum, but the muslin with its colouring matter, was

in *close* and *immediate* contact with the inner surface of the glass, and with the quicksilver in every other part; so that nothing else could possibly reach the colouring matter, excepting the light passing through the glass. In the second experiment, the muslin was placed *in vacuo*, but the colouring matter, was equally protected by the glass and quicksilver from the access of every thing but light. In both experiments, the bits of muslin employed, were perfectly dry, and the quicksilver, when brought into contact with them, occasioned no change or impression whatever, upon the colouring matter, not an atom of it adhering thereto, or to any part of the muslin. The changes of colour therefore could only have been occasioned by the sun's rays, and it is now well known, that their most common and general effect upon colouring matters is, that of separating oxygene:—their other effect, of promoting a combination of it, could not possibly have been produced in these experiments, where no oxygene existed. Wishing, however, to obtain as much additional evidence as possible, concerning the sort of action exercised by the sun's rays, in producing the changes before mentioned, I took a piece of muslin impregnated, &c. as in the former experiments, and having wetted it with water, which had just boiled and was partly cooled, I spread the muslin on white paper, in a place accessible to the sun's rays, and separating the latter by a triangular prism, I brought the solar spectrum to bear completely upon the colouring matter of the buccinum, and was soon convinced that the usual changes of colour proceeded faster and more distinctly under the *deoxygenating rays*, at the *violet* extremity, than they did at the other extremity under the red rays; the muslin becoming *purple* at the former, whilst at the latter it had become only *blue*.

There is, moreover, another proof of the separation of oxygene, when the purple under consideration is produced, and it is connected with the strong disagreeable odour, nearly resembling that of *garlic*, which was so distinctly perceived by Cole and Reaumur, and which has constantly assailed my nostrils, whenever the colouring matter of the buccinum began to turn green, and has continued to do so, without diminution, until some time after the purple colour was fully produced. This odour to my senses, unequivocally indicates the presence of phosphorus, which is contained in all animal substances; and, when subjected to the action of the sun's rays, readily becomes volatile in part, by combining with a portion of oxygene; and this volatile part or compound (which, as Davy observes, p. 287, "should, according to the principles of the French nomenclature, be called *phosphorous acid*") emits an offensive *alliaceous smell*, very much like that of the colouring matter of the buccinum, when it becomes purple. The last, or that part of it which gives the smell of garlic, readily mixes with water, and strongly impregnates it with this odour, as I have found by many experiments; and in this respect it also agrees exactly with the volatile compound which gives the alliaceous odour from phosphorus.

I repeated Reaumur's experiment with corrosive sublimate of mercury, and found that the purple which resulted, partook more of the blue tint than usual, and this appeared to be the case when the colouring matter of the buccinum was mixed with sulphate of iron.

Pliny, as my readers will have seen, represents the purple colour obtained from the buccinum, as not being permanent, without a mixture of that from the purpura; but on this point he was certainly misinformed, it being of itself the most durable of all animal colours. I found

that it was not sensibly affected, even upon fine muslin, by being *wetted* with undiluted oxymuriatic acid, though when immered in a phial filled with this liquor, it soon disappeared, as I believe would happen to almost every other animal or vegetable colour. I found also that undiluted oil of vitriol dropped upon a bit of calico, which had been made purple by the matter of the buccinum, *did not destroy the colour*, though it produced a tinge inclining more to the *blue*. Highly concentrated and smoking nitrous acid, applied to a similar bit of calico, changed the purple to a yellow colour, which became very lively and beautiful, upon being rinced in a solution of potash. Thinking it not unlikely that this change might have resulted from a combination of oxygene, with the colouring matter, rather than from an *irreparable decomposition of it*, I exposed the yellow in question to the direct action of the sun's rays, to see whether their deoxygenating power would reproduce the purple, but no such effect ensued; the yellow remaining, and seeming to be permanent. Strong muriatic acid applied to a similar bit of calico, appeared to have no effect upon the purple colour; and single aquafortis changed it less than the much weaker oxymuriatic acid.—But I will proceed no farther with my observations, believing that I have now sufficiently explored and elucidated this hitherto abstruse subject. Some of my readers may indeed think that I have been too minute in my statements concerning it. But to me, the colouring matter under consideration, has appeared to deserve my utmost attention, because, (independently of the veneration with which it was contemplated by the ancients) its properties are more extraordinary, more interesting, and more instructive, than those of any other. It is strictly and pre-eminently intitled to the distinction of a *substantive* colour, as it may be permanently fixed,

even upon linen and cotton, by the most simple application, and without any preparation or admixture whatever: and it is admirable, for the singular constancy with which it proceeds, through the series of intermediate colours, (according to their prismatic arrangement) until it has permanently *fixed itself*, and attained that purple tint, which the Author of Nature, for some unknown purpose, has fitted it to display; and all this, *in spite*, if I may so express myself, of many powerful chemical agents, whose utmost influence extends only to retard, for a few hours, the ultimate accomplishment of this its destiny.

The celebrated Fontenelle, in giving (as Secretary of the Royal Academy of Sciences at Paris) his account of Reaumur's discovery, began by observing, that not only more things were found in modern, than had been lost in ancient times, but that it was even impossible for any thing to be lost unless mankind were willing that it should remain so; it being only necessary to search in the bosom of nature, where nothing is annihilated; and that to be certain of the possibility of a thing's being found, was a considerable step towards finding it. But before the buccinum and purpura were found by Cole, Reaumur, and Duhamel, America had been discovered, and new dyeing materials thence obtained, superior in beauty, and especially in cheapness, to those so highly valued in ancient times; though it must be confessed that no other substance will afford a substantive purple of equal beauty and durability, and capable of being topically applied to linen and cotton with so much simplicity and expedition; and for these reasons it seems probable that the discoveries of these gentlemen might still be rendered beneficial in staining or printing fine muslins, for which but little colouring matter is required. And indeed, there was a species of

buccinum found more than a century ago near Panama, on the coasts of Guayaquil and Guatemala, of which constant use appears to have been made in those countries, for the dyeing or staining of cotton, as Jussieu, the elder, Thomas Gage, and others have mentioned. Don Antonio Ulloa, in particular, says, "they are something larger than a nut, and contain a juice which, when expressed, is the true purple; for if a thread of cotton or the like be dipped into this liquor, it becomes of a most vivid colour, which repeated washings are so far from obliterating, that they rather improve it; nor does it fade by wearing." "This precious juice," continues he, "is extracted by different methods; some take the fish out of the shell, and laying it on the back of the hand, press it with a knife from head to tail, separating that part of the body into which the compression has forced the juice, and throw away the rest." This being done, "they draw threads through the liquor which is the whole process; but the purple tinge does not appear immediately, the juice being at first of a milky colour, from which it changes to a green, and, lastly, to this celebrated purple." See the translation of his account of the voyage to South America, &c. vol. i. p. 268-9.

Snails, with the same property, exist in various other parts of the world. Catesby, in describing the Bahama islands, (vol. i. p. xliv.) mentions among the shells there, the "Buccinum brevi rostrum muricatum, ore ex purpuro nigricante dentato," adding, "these shells stick to rocks a little above low water, and are consequently a short time uncovered by the sea. They yield a purple liquor, like that of the murex, which will not wash out of linen stained with it."

Josselyn also, in his New England Rarities discovered," p. 37, says, "at Paschataway, a plantation about 50 leagues by sea, eastward of Boston, in a small cove,

called Baker's Cove, they found this kind of muscle, which hath a purple vein, which being pricked with a needle, yieldeth a perfect purple or scarlet juice, dyeing linen so that no washing will wear it out, but keeps its lustre many years: we mark our handkerchiefs and shirts with it. Mr. John Nieuhoff moreover relates, that "*abundance* of purple snails are found in the islands over against Batavia." "They are boiled (adds he) and eaten by the Chinese, who have a way of polishing the shells, and pick out of the middle of the snail a certain *purple*-coloured substance* which they use in colouring, and in making red ink."

In the fiftieth volume of the Philosophical Transactions, Dr. J. A. Peysonnel, F. R. S. describes what he calls the naked snail producing purple, ("Limax non cochleata, purpur ferens,") as being found in the seas of the Antilles, and "precious for the beautiful purple colour it produces in the same manner that the cuttle-fish produces its ink." "There is (continues he) a hollow in the back of the animal, where the canal, filled with a reddish juice, passes out, carrying it to a fringed body like a mesentery; and it is there the purple juice is brought to perfection." "When the animal is touched, he makes himself round and throws out his purple juice as the cuttle-fish does his ink: this juice is of a beautiful deep colour; it tinges linen, and the tincture is difficult to get out."

It is however to be remarked, that the liquor of the naked snail exists naturally of a purple colour, without

* Probably this description is inaccurate, for if the substance in question, exhibits a purple colour, when taken immediately from the body of the snail, it must differ in its nature and properties from the purple of either the murex or buccinum, and nearly resemble that of the snails, mentioned in the succeeding paragraphs.

the application of light; a circumstance which denotes very different properties from those of the buccinum. In Brown's History of Jamaica, there are descriptions of two shell-fishes having a similar colouring liquor; one is termed "the larger dark lernea, or sea snail, frequent in the American seas." Dr. Brown observes, that "on touching this creature, it emits a considerable quantity of viscid purple liquor, which thickens and colours the water about it so much, that it can scarcely be seen for some time after, by which means it is generally enabled to make its escape in times of danger." "I have gathered," adds Dr. Brown, "a small quantity of the discharges of this creature, and stained a linen handkerchief with it; it gives a very beautiful dark purple colour, which is not apt to change with either acids or alkalies; but is easily washed out:" a circumstance in which it totally differs from the buccinum, &c. as well as in that of the liquor being naturally emitted of a purple colour. The other, of these shell-fishes, is termed cochlea ima, or the purple ocean shell; and upon being touched, "it diffuses a beautiful purple liquor," says Dr. Brown, which seems to resemble the former. The sepia, or cuttle-fish, has long been known to provide for its safety in like manner, by discharging in times of danger, a viscid bitter black fluid, which Rondeletius mistook for bile, and which, I know by experiments, to be as dissimilar as possible, to the colouring matter of the buccinum, and utterly incapable of serving any useful purpose in dyeing; and I am persuaded, this must be true also, of the liquor of Dr. Brown's shell-fishes, and that of Dr. Peysonnel's naked snail. A similar mistake seems to have been committed by M. Cuvier, one of the latest, most respectable, and best-informed writers upon comparative anatomy, who has evidently confounded the *testacca*, affording the purple of the

ancients, with a considerable number of the vermes of Linnæus, (principally molluscæ) naturally destined to secrete, and when in danger to *eject*, dark-coloured fluids, that, by obscuring the water, they may be enabled to escape; a purpose totally different from that of any fluid secreted by the murex or buccinum, and affording the purple of the ancients. See Cuvier's Anatomie Comparée, tom. v. 263, 4.

Mr. Martin Lister, (see Philosophical Transactions, vol. vi.) observes, that " the common hawthorn caterpillar will strike a purple, or carnation, with ley, and stand; the heads of beetles and pismires will, with ley, strike the same carnation colour, and stand; and the amber-coloured scolopendra (adds he) will give, with ley, a most beautiful and pleasant amethystine, and stand:" but whether he means that they will stand in this way, when applied to paper only, or to the substances usually made to receive dyes, does not appear. In another part of the same volume, Mr. Lister mentions an insect (cimex,) whose eggs, bruised upon white paper, " stain it of themselves, without any addition of salt, of a lively vermilion colour."

CHAPTER V.

Of Vegetable Substantive Colours, and principally of Indigo, and the Plants affording it, or a similar Colour.

"Combien de tentatives n'aura t'on pas fait, avant que de parvenir au point d'appliquer convenablement les couleurs, sur les etoffes, et de leur donner cette adherence et ce lustre, qui fait le principal merite de l'art du teinturier, un des plus agreables, mais en meme temps un des plus difficiles qu'on connoisse!" GOGUET *de l'Origine des Lois, des Arts, et des Sciences, &c. tome premier,* 4to.

THE subject of this article is the most interesting, important, and instructive, which can occupy the attention of a dyer, or a chemist; the admirable and singular properties of indigo being only surpassed by those of the colouring matter of the murex and buccinum, a little, while it is of much higher practical utility than the latter. From the remotest ages of which we have any correct information, mankind appear to have possessed and employed the means of dyeing or staining *blue* colours substantively, either upon their skins or clothing. In the more temperate climates, this was done from the plant denominated *isatis*, by Linnæus, as well as by the Greeks and Romans, and commonly known in this country by the name of woad: but in warmer situations, the colour in question was chiefly obtained from some of the indigoferæ (of Linnæus), or other vegetables of the natural order of Papilionacæe, or that of leguminosæ. The plants so employed, all contained more or less of the *basis* of indigo, combined with but a *small* portion of oxygene, and therefore capable of being extracted, and held in solution by water, long enough at least for its application as a dye. And it is not therefore surprising that the inhabitants of all countries, excepting India, should have thought it sufficient to pound or grind the plants naturally containing this

basis; and after a partial and premature fermentation, in some places, to dry the matter so pounded or ground; leaving the dyer, when necessary, to macerate and give it an additional, or other sufficient fermentation, to enable the basis to absorb such farther portion of oxygene, as, when assisted by the dyeing process, would fix it permanently in the dyed cloth, and fully manifest its *blue* colour.

This *partial* fermentation of the bruised plant, previous to its being dried, was chiefly practised in regard to the woad or *isatis*, of which two species, differing but little from each other, are cultivated in Europe, viz. I— Tinctoria, and I— Lusitanica:* with the indigo plants

* The preparation given by the Greeks and Romans to the isatis, is not I believe described by any of their writers, but that of the moderns is well known. The plant, after being cut, washed, and partly dried, is carried to a mill, and there ground to a paste, after which it is formed into a mass or heap, and being covered to protect it from rain, is left to undergo a partial fermentation for about a fortnight.—The heap is then stirred, well mixed, and formed into balls or cakes, which are exposed to the sun and wind to dry, and thereby obviate the putrefactive process, which would otherwise take place. Being afterwards collected in heaps, these balls again ferment, become hot, and emit the odour of ammonia or volatile alkali, which, as Mr. Hume tells us, in the 44th chapter of his History, gave such offence to Queen Elizabeth, that she issued an edict to prohibit the cultivation of this plant: had she prohibited the making it to ferment, except by the dyer, she would have acted more wisely. After the heat has continued for some time, these balls fall into a dry powder, and are then sold to the dyer, who now seldom employs them without a mixture of indigo, which last the woad helps to deoxygenate and render soluble. Formerly, however, this preparation, fermented by well-known means, was employed *alone*, though it was incapable of giving a deep and bright blue colour, because the tingent matter was in union with too great a proportion of the other constituent matters of the plant. The colour, however, which it did give, was very durable. But the best methods of conducting the fermentation and preparation of woad

this sort of fermentation seems not to have been thought necessary,* by a great part of mankind.

are, even at this time, so little understood, by the persons exercising that employment, that the goodness of any parcel of it can never be ascertained, otherwise than by the actual use which dyers afterwards make of it, and this commodity is therefore purchased under the greatest uncertainty respecting its true value, and it would therefore be better to dry and sell it unfermented. It has lately suited the policy of the French government, to cause the isatis to be cultivated for the purpose of obtaining indigo from it, by a process analogous to that employed in the East and West Indies, with the indigofera tinctoria, and I have seen some of the indigo so produced, but I do not think that in goodness and cheapness it can ever rival that from the indigo plants, which at the proper age will afford nearly thirty times as much indigo, as an equal weight of the isatis tinctoria.

* François Cauche, after describing the indigo plant at Madagascar, says the natives, " pillent les feuilles avec leur branches, etant encore tendres, et en sont des pains, chacun de la pesanteur de trois livres, qu'ils font sécher au soleil; s'ils veulent teindre, ils en pillent un, ou deux, ou trois, suivant qu'ils en ont besoin, et mettent la poudre dans des pots de terre, qu'ils font bouillir avec de l'eau sur le feu puis tirent leurs pots, laissant refroidir cé qui est dedans, y trempant leur cotton et leur soye." Voyage de Francois Cauche, en l'isle de Madagascar, &c. 4to. Paris 1651. p. 151. M. Adanson gives a similar account of the method of using the indigo plant by the natives of Senegal, except that he mentions, as perhaps Cauche ought to have done, that a ley of vegetable ashes is employed in dyeing with it. See his voyage, &c. Capt. George Roberts also, in the account of his four years' voyages, mentions the indigo plant as growing wild at Bonavista, one of the Cape de Verd islands; and that the natives prepare it, " only by pounding the leaves of the shrub while green, in a wooden mortar, with a wooden pestle, and so reduce it to a kind of pap, which they form into thick round cakes, or balls, and drying it, keep it till they have occasion to use it for dyeing their clothes."—He observes " that the cakes in drying, change from a green to a blue colour, (probably by absorbing oxygene) and that the natives extract the dye by means of a lixivium," as I suppose, of wood ashes. Mr. Mungo Park, in the account of his travels in Africa, says, that to dye cloth

By what circumstance or event the people of Hindostan alone were led, several thousand years ago, to discover and adopt means by which the blue colourable matter of the indigo plant might be extracted, oxygenated, and precipitated, free from almost all the other matters naturally combined with it, and afterwards brought into the dry solid form in which we now find it, no one can I believe conjecture. But, as an accurate knowledge of the process by which all this can best be effected, will greatly conduce to a right understanding of the nature and constitution of this wonderful, and most valuable production, I shall endeavour to give the best possible account and explanation of it, availing myself of every thing which has been done by others, as well as by myself.

of a lasting blue colour, according to the practice of the negro women, "the leaves of the indigo when fresh gathered, are pounded in a wooden mortar, and mixed in a large earthen jar, with a strong ley of wood ashes, (chamber-ley being sometimes added) and the cloth is steeped in this mixture, and allowed to remain until it has acquired a proper shade."—"When indigo is most plentiful, they collect the leaves, and *dry them in the sun*, and when they wish to use them, they reduce a sufficient quantity to powder, and mix it with ley as before mentioned." Vol. i. p. 97.

Mr. Marsden, in his History of Sumatra, p. 78, says, "the indigo shrub (Taroom) is always found in their plantations, but the natives to dye with it, leave the stalks and branches for some days in water to soak, then boil it, and with their hands, work some chunam (quicklime) among it, with the leaves of the pacoo sabba (a species of fern) for fixing the colour. They then drain it off, and use it in a liquid state."

To conclude this note, I shall only add the following extract from Mr. Barrow's Travels in China, p. 560, "Near most of the plantations of cotton we observed patches of the indigo; a plant which grows freely in all the middle and southern provinces. The dye of this shrub, being *no article of commerce in China*, is seldom if ever prepared in a *dry state*, but is generally made to communicate its colouring matter *from the leaves*."

It has been already stated, and will hereafter be abundantly proved, that indigo principally, and *essentially*, consists of a peculiar colourable matter, which I call its *basis*, and which being combined with a certain portion of oxygene, is, while this combination subsists, thereby rendered *insoluble* by any means yet known, excepting those which exert an agency, more or less *destructive* upon the *basis itself.* This basis is colourless when destitute of oxygene, and seems to be *formed* by certain *peculiar* secretory organs, bestowed upon a few particular plants, some of which have been already noticed, and others will be mentioned hereafter: but though it manifests a strong affinity for oxygene, when separated from the different matters with which it is mixed in the plant, the basis is naturally combined with so little of it, as to be liable to decomposition and injury from various causes, which would have no such effect upon it, when sufficiently oxygenated, as it is in the state of indigo. I have observed repeatedly, by gathering the fresh leaves of the indigo plant, inclosing them in a piece of white calico, and pressing the latter strongly upon the leaves, so as to make it imbibe their juice, that a greenish tinge was first produced on the calico, which in *drying*, approached to the blue, and ultimately assumed that colour; though it was very pale, because the proportion of colouring matter, or rather of its basis, naturally dispersed through the juice of the plant, was too small to produce any other than a feeble colour—it was however so completely fixed, that repeated washings with soap, had only the effect of rendering it brighter by removing the other matters contained in the juice of the plant, and applied to the calico with the blue colouring matter. By repeating these applications (of the juice of the leaves in question) to the *same piece* of calico several times, I found that an addition of blue colour

was made by each, and as the colour so communicated was permanently fixed, I have concluded that in regard to the *degree* of its oxydation, the basis of indigo so applied, was nearly in the state, in which it commonly is, in the composition to be hereafter described, which the calico printers apply by the pencil, to give permanent blue stains, or figures. I suspect, however, that the basis of indigo, when thus applied to calico, in union with the *unfermented* juice, does not afterwards oxygenate itself so perfectly, as it does when made into indigo, by the process about to be described. The juice expressed from the bruised leaves of the indigo plant, and exposed with a wide surface to the rays of the sun, between the tropics, and thus evaporated to dryness, before any fermentation had taken place, acquired only a greenish blue colour; partly, as I think, because the basis of the indigo was but imperfectly oxygenated, and partly because it continued to be mixed with a yellow extractive matter, and a greenish resin, which are both naturally contained in the indigo plant, as M. Chevreul has ascertained; (see Ann. de Chimie, tom. 68.) though, by the common process of fermentation, and precipitation, the indigo is in a great degree separated from them, as well as from the other matters contained in its juice.

It would be a deviation from my subject, were I to give any account of the cultivation of the indigo plant: I may, however, be permitted to observe, that the species of the genus indigofera, most frequently employed, are first,—Indigofera anil, a large hardy plant growing wild in the hotter parts of America, and affording indigo of good quality.—

2. I— Tinctoria; which, according to Loureiro, grows spontaneously, as well as by cultivation, in China, Cochinchina, Hindostan, Coromandel, and other parts of India, whence it was carried to America. It is called

indigo franc, by the French, and is less hardy, though more productive than the other species.

3. I— Disperina; this I consider as the species called guatamala indigo, which yields a fine pulp, but is less productive than the preceding; and

4. I— Argentea. This is called indigo batard, by the French; and, as Linnæus says, was also a native of the East Indies. All these are suffruticose plants, or under shrubs; and they all have a peculiar smell, which is offensive to cattle.

The stems, with their leaves being cut, (which is best done when the plant is in full blossom,) are placed in large vats, called *steepers*, and pressed down by planks and wedges: in some places this is done immediately after being cut; in others, after being more or less dried;* an operation which probably facilitates the solution and extraction of the indigo basis; as the falling of rain upon *hay*, is found to deprive it of a greater portion of its nutritious parts, than *grass* recently mowed, would have lost by the same means. Being properly placed in vats, the leaves and twigs are covered with water; which has hitherto been most frequently employed *cold;* and when this is done, the appearances which follow, are thus described by Dr. Roxburgh.†

* In a MS. relating to the manufacture of indigo, belonging to Sir Hans Sloane's collection, in the British Museum, (No. 4020, of Ayscough's catalogue) I find it asserted, that in some parts of the East Indies, they collect the leaves of the indigo plant into great heaps, and leave them to grow hot and sweat, before they are steeped. In Egypt they grind the plant, after it has been soaked an hour in water of the temperature of 70° of Reaumur, or 190° of Fahrenheit, by which the extraction of the indigo basis is facilitated, but the broken parts of the plant afterwards become mixed with the indigo, and render it impure.

† As a supplement to the former edition of this volume, I was induced to publish (with some observations of my own) an abstract

"In a few hours, more or less, according to circumstances, a slight motion begins to pervade the body of the liquor in the vat; the bulk increases considerably, with some additional heat; air bubbles are generated, some of which remain on the surface: these gradually collect into patches of froth; a thin violet, or copper-coloured pellicle, or cream, makes its appearance between the patches of froth; soon after, the thin film which forms the covering of the bubbles that compose the froth, begins to be deeply tinged with fine blue. The liquor has from the beginning been acquiring a green colour, and now it will appear, when viewed falling from one vessel into another, of a bright yellowish *green*, and will readily *pass the closest filter*, until the action of the air makes it turbid; a proof that the base of the colour is now perfectly dissolved in the watery menstruum: this is the time for letting off the vat. If suffered to remain, the bulk begins to diminish, and returns

of a MS. which had been put into my hands at the East India House, containing an "account of a new species of *nerium*, the leaves of which yield indigo," &c.; with a second part, containing "*the result of various experiments made with a view to throw some light* on the theory of that beautiful production: and an appendix containing a botanical description of a second new indigo plant; the whole illustrated with drawings, and addressed to the Honourable Sir Charles Oakley, governor, and president in council at Fort St. George, to be transmitted to the Court of Directors of the United East India Company, and committed to their protection," &c. By William Roxburgh, M. D. But as the whole of that MS. with some few additions and explanatory engravings, has been lately, (and in some degree upon my suggestion) printed as a part of the 28th volume of the Transactions of the Society of Arts, Manufactures, and Commerce, I am enabled to abstain from a republication of my former abstract, though I shall, at the proper places, avail myself of the most interesting of Dr. Roxburgh's facts; taking them from this last mentioned volume of the Society of Arts, &c. to which my references will be made.

to its original dimensions; however, the fermentation continues; there is still much intestine motion through the vat, and large quantities of froth are formed. Hitherto the peculiar *smell* of the plant has prevailed, but now it becomes very offensive, something like that of animal matter beginning to putrefy. As fermentation goes on, the *smell* becomes more and more offensive, and the quantity of airs discharged less and less, until absorption takes place."

This first macerating and fermenting *process*, occasions an extraction of the indigo basis, and an imperfect oxygenation of it: but in other respects I do not know that it is of any importance, to the production of indigo. Other plants, in similar circumstances, would ferment with an evolution of carbonic acid gas; and doubtless the various extractive matters of the indigo plant, participate and co-operate in producing the appearances just described by Dr. Roxburgh; who has, however, ascertained that in the *first* part of this process, there was *a great absorption* of, or from the atmosphere, (the free access of which was indispensably necessary to the fermentation), and this absorption doubtless consisted principally of oxygene. He found, moreover, that as soon as the bulk of the mass began to be enlarged, a disengagement of airs took place, which he describes as being "*fixed*, pure, and impure," (meaning, I presume, carbonic acid gas, oxygene, and perhaps hydrogene.) "But, continues he, about the time that the bulk of the vat is greatest, the fixed air is discharged purer, and in larger quantities than at any prior period." "I tried," he adds, "every means I could invent, to detect the volatile alkali, that I was led to expect, but without the smallest appearance of success, at any time." If, as soon as the fermenting liquor becomes green, an alkali be added to it, a precipitation, says *M. Dutrone*, will take place, "d'une fecule verte extremement belle;" and at a

more advanced state of the process, which he calls "la fermentation putride," alkalies, according to his account, will precipitate a "fecule qui porte une couleur bleu de ciel très legere."

The fermentation being completed, the green coloured liquor is drawn off, from the steeper, into the *beating vat*, or receptacle, (which the French call *batterie*,) where it is violently agitated, commonly by machinery, during one, two, or three hours, according to the means adopted, and the force with which they are employed; the effect of this agitation is analogous to that of churning, for by promoting a farther oxygenation of the basis of indigo, it renders the latter *insoluble*, in the liquor, which had previously held it dissolved; and thereby causes it to granulate, or collect into small particles, or little floculæ, *suspended, but not dissolved*, in the aqueous menstruum which still retains, in solution, the other matters extracted from the indigo plant, and by so retaining them, enables the manufacturer to separate the former from the latter, by adding lime water, or some other suitable *precipitant*, which is to be mixed with the liquor, as soon as a *distinct* granulation becomes manifest.*

* Dr. Roxburgh has believed, that the basis of indigo, during the fermenting process, was held in solution by carbonic acid, and that agitation and precipitants were afterwards useful, the former by *extricating* this acid, and the latter by *absorbing* it. That such effects are produced, may be presumed by the discharge of carbonic acid gas, which is manifest during the agitation of the liquor, and by the cessation of that discharge, when either lime water, or caustic alkali is added. But that this agitation answers another, and more important end, may be proved even from some of Dr. Roxburgh's experiments to be presently noticed; and that lime water may act as a *precipitant*, *otherwise* than by absorbing carbonic acid, is certain, from its well known power of throwing down many colouring matters, when they are held in solution, where no carbonic, or other acid is present; in such cases the lime acts by its particular affinity for these colouring matters, in the same way in

During this last *agitating*, or oxygenating process, "fixed air, (says Dr. Roxburgh,) continues to be discharged, with pure and impure airs; but still nothing like volatile alkali." But when the precipitant is added, "from that instant an absorption of air takes place; and after the liquor has settled a little, a candle will burn freely close to its surface."

The most efficacious precipitants hitherto employed are pure well-burnt lime water, and the different alkalies, especially when in their caustic state;* and some of

which, as Dr. Roxburgh observes, "a solution of tin in aqua regia (in a very small proportion) gives a large produce of light blue precipitate," when added to the liquor in question. Alum acts in the same way, but by throwing down at the same time the other extractive matters of the plant, it debases the quality of the indigo.

* Concerning the expediency of *precipitants*, Dr. Roxburgh delivers the following opinion: "The coloured liquor, impregnated with the first principles of the drug, (its base) whether acquired by fermentation, or by a scalding heat, will, without the least of our assistance, if only exposed to the open air, and particularly if with a large surface, in a short time begin to part with its colour, which will fall to the bottom in minute grains of fine blue indigo: agitation will hasten the separation and precipitation *much*, and cause the produce to be larger. Heat has nearly the same effect, though in a less degree, except when joined with agitation, in which case the two act more powerfully than either alone. The indigo procured by these means is good, if the process has been properly conducted; precipitants are not therefore absolutely necessary for the production of indigo, but if well chosen, and in a proper proportion, they forward the operation *much*, causing a larger produce than could be had without them; and I have reason, from a variety of experiments, to say, that the quality is by no means injured in consequence."—Dr. Roxburgh thinks lime water preferable to any other precipitant; alkalies, he says, "answer the best when made caustic, but even then lime water gives a purer indigo, though probably not in quite so great a quantity." He adds that "if lye perfectly caustic be added, before the liquor has been agitated, or before any granulation has taken place, the extractive matters of the plant will generally be precipitated first, in the form of a dirty pale yellow fecula: in the mean time the supernatant liquor gradually

these in suitable proportion being well mixed, and the liquor left at rest for six or eight hours, the blue-coloured matter will commonly be found to have all subsided to the bottom, leaving the supernatant liquor of a clear brandy, or Madeira wine colour: when it appears more or less green, or olive-coloured, we may conclude the separation and precipitation of the indigo have been but imperfectly performed: this happens indeed but too often, and Dr. Roxburgh conceives "it to be owing to the presence of fixed air, (carbonic acid gas) still adhering to, and keeping dissolved a portion of the base" of indigo. I think it more probable, however, that a part of the basis of the indigo is, in such cases, hindered by the presence of carbonic acid, from attracting and uniting to itself a sufficient portion of oxygene to cause a separation of it by precipitation from the other extractive matters yielded by the plant; it having been found, that by renewing the agitation, of such green or olive-coloured liquor, and adding precipitants to it afterwards, more indigo may be obtained.*

acquires from the surface a deep blue colour, soon becoming turbid, and lastly the blue precipitate of real indigo will be formed over the first." P. 281, et seq. Precipitants, therefore, should not be added to the liquor until the indigo basis has been sufficiently oxygenated; which, among other appearances, may be known by a change in the colour of the froth on its surface, which, after appearing *blue*, becomes *colourless*, because the blue matter which gave it that appearance being no longer dissolved, *subsides* from the froth.

* As the profit of the indigo maker greatly depends upon his knowing when to stop the fermenting, as well as to the agitating, process, it may be proper that I should subjoin a few observations upon each.

The fermentation begins soonest when the weather is hottest, and when the vat has been recently employed for the same purpose; as it then retains a kind of fermenting leaven. If the fermentation be

Dr. Roxburgh ascertained by experiments, which are minutely described at pages 278—281, of the volume before mentioned, that some of the green indigo liquor, taken when just fit to be drawn off from the fermenting

stopped too soon, a considerable part of the colourable basis will be left unextracted, and *lost* in the plant: to avoid this loss, handfuls of the twigs and leaves are frequently drawn from the vat, that it may be ascertained whether they are become of a *pale yellow*, and the young tops made tender. Regard should also be had to the colour of the liquor, which, so long as the fermentation has been deficient, will have only attained a yellowish green, with a copious greenish froth, capable of being easily dispersed by a few drops of oil, which is not the case when the fermentation has been carried too far. In this last event, the froth or scum generally subsides, and the green colour of the liquor will lose its brightness, appear brownish on the surface, and become turbid, from an excessive dissolution and extraction of the various matters belonging to the plant. The liquor which has suffered in this way, cannot bear much agitation afterwards, without farther injury to the indigo resulting from it; which will become either blackish or of a dull *slate* colour, and be found very little susceptible of either granulation or precipitation; and even with moderate agitation, the liquor which has undergone this excessive fermentation will never afford good indigo. But where the fermentation has, on the contrary, been *deficient*, though the quantity of indigo to be obtained will be small, the quality may be improved by a greater degree of agitation. When too little of this last is given to liquor which has not been fermented sufficiently, the indigo will manifest a coarse grain, and not only prove less in quantity, but its blue colour, instead of the coppery gloss, will retain a greenish cast. I will here add, in regard to the precipitants, that the Javanese, as M. de Cossigny relates, avoid the want, and use of them, by first fermenting the indigo plants, and then *boiling* the liquor for a little time before it is agitated. It is not, I believe, the practice to put water a second time upon the indigo plants in the fermenting vat, in order to extract or wash out any remnant of the indigo basis, left in, or adhering to the plant, after the fermented liquor has been drawn off; but I am persuaded, that if this were done, and this washing, or second extract, were added to the first, a considerable portion of indigo might be obtained, which I believe to have been hitherto lost.

into the agitating vat, and impregnated with carbonic acid gas, (in Dr. Nooth's apparatus,) would afford no granulation or precipitation of indigo. This was also the case with liquor obtained by scalding the leaves of the indigo plant in large earthen bottles. The liquor thus obtained, always became of a yellowish green, and the bottles containing it, being inverted in a large vessel of water, the liquor remained *unchanged* for a month; but, being taken out, and *atmospheric air freely admitted* to the liquor, *greenish blue veins were observed to spread, from the surface downward, until the whole became blue;* and then a precipitation of indigo soon commenced. This experiment was often repeated with the same result; and Dr. Roxburgh justly infers from it, that carbonic acid is not the agent, by which the colouring matter of indigo "is separated from its menstruum." Some of the same green liquor, being impregnated with nitrogene, from iron filings, and diluted nitrous acid, (in Dr. Nooth's apparatus) a violet-coloured film was produced, after some hours; but no other change took place, until the admission of atmospheric air, when the usual granulation and precipitation of indigo soon followed.

Some of the same green liquor, being impregnated, in the same way, with hydrogene, from iron filings and diluted sulphuric acid, it "was quickly covered with much of a deep voilet-coloured scum, but no decomposition took place, till the atmospheric air had obtained access to the liquor, when it quickly became of a deep greenish blue, and let fall a considerable proportion of precipitate, which, on drying, turned out to be the most beautiful indigo."

In addition to these experiments, Dr. Roxburgh tried repeatedly, with the same green liquor, admixtures of lime water, volatile alkali, caustic lye, stale urine, prussiate of potash, &c. and they all concurred, says he, to

"prove clearly, that the most powerful precipitants, added to these liquors, *cause no decomposition, without the help of the open air.*"

Though Dr. Roxburgh had thus ascertained, *the indispensable necessity of something*, obtained from the *open air*, to produce a granulation, and precipitation of indigo, and though he had also ascertained that this *thing*, could not be either carbonic acid gas, or nitrogene, or hydrogene, or ammonia; he did not suspect it to be oxygéne, until the former edition of this, my first volume, had fallen into his hands; then however, (as I had predicted) he, with laudable candour, relinquished his belief of the supposed agency of *phlogiston*, in producing these effects; and declared himself convinced, that "oxygene is the colouring principle of indigo."*

* The following is extracted from a letter written by Dr. Roxburgh, to Robert Wissett, esq. and dated Calcutta, 29th October, 1797.

"I have seen the heads of my essay on indigo published, and commented upon by Dr. Bancroft. In consequence of seeing so good an use made of it, I am encouraged to send to your care, by Mr. Brown, the surgeon of the Albion, a package of a colouring drug, which I do not imagine has ever reached Europe. viz. the coloured tubes of the blossoms of *Nyctanthes* arbor tristis, of Linnæus. The Hindoos use them to give a most beautiful orange colour to cotton cloths; but with them the colour soon fades. I will thank you to give the parcel to Dr. Bancroft, and also beg of you to inform him, that *I am now a convert to his opinion*, viz. *that vital air, or oxygene, is the colouring principle in indigo.*—The *hot water* process begins to be used over these provinces, by some of the best manufacturers; with it they can make indigo, *when the weather is too cold* for the usual process of fermentation, and it gives a more beautiful and lighter indigo, like the guatamala, or fine Spanish flora. I send you a sample of some made by Mr. Pope, of Cossimbuzar, a most valuable farmer."

When Dr. Roxburgh was lately in Europe, he obligingly left with me, not only samples of the indigo here mentioned, (and which is truly excellent,) but of many other sorts, manufactured in different ways, from different kinds and species of vegetables yielding indigo,

M. Berthollet seems not to have well understood the effect of some parts of the process lately described. He says, tom. ii. p. 42, that the atmospheric air does not appear to intervene or partake in the fermentation, because there is a discharge of inflammable air. But it was fully ascertained by Dr. Roxburgh, that a copious *absorption* of air from the atmosphere, did occur; and that oxygene did combine with the basis of indigo, in a considerable degree, during the fermentation, was manifested by the *progressive change*, which as usual constantly took place in the *colour of the liquor*, during the fermentation, until

and with different precipitants, &c.; all serving either to confirm or illustrate particular facts respecting this interesting subject: but a distinct account of them would occupy too much space.

The scalding, or "hot water process," mentioned in the preceding extract, had been previously recommended by Dr. Roxburgh, and is, indeed, absolutely necessary to obtain indigo from the leaves of the nerium tinctorum, which affords none by fermentation, with water moderately warm. It is employed, as the Doctor informs us, by "the natives throughout the northern provinces or Circars," (of Coromandel) and "in many parts of the Carnatic," in making indigo from the common indigo plant. Among the advantages stated to result from it, are,—First, that of a more complete and certain extraction of the basis of indigo, (by thus subjecting the plant to the action of water, heated to about 150°, or 160°, of Fahrenheit's scale,) than can be expected by the fermenting process; with which the plant, as M. de Cossigny asserts, (Treatise on Indigo, p, 145,) will yield indigo, upon being fermented a *second* time.—Second, that of not injuring the health of labourers employed in it; the carbonic acid gas, and putrid miasma exhaled by it, being much less than by the fermenting process.—Third, that of requiring less agitation; because the heat employed, greatly promotes the absorption and combination of oxygene.—Fourth, that of completing the operation much sooner, so that it may be performed two or three times daily, upon a large scale.—Fifth, that of affording indigo, which dries quickly, without acquiring any bad smell; and which "has never that flinty appearance common to fermented indigo; but in softness and levity is like, or even superior, to Spanish flora."

it acquired a full green, and even blueish colour, the froth or scum becoming more or less blue, at the same time; this change was not unknown to M. Berthollet, but instead of ascribing it to the *oxygenation* of the indigo basis, he supposed it to result from the separation, or destruction of a *yellow* substance, which gave the plant a greenish tint; thus intimating, that the indigo had existed naturally of a *blue colour in the plant*, which certainly is not the fact.

Some of the manufacturers of this commodity, in the East Indies, have lately purified their indigo, by taking it immediately from the small dripping *vats*, and boiling it in copper vessels, with water and fossil alkali, (soda), and afterwards carrying it to what are called the dripping *tables*, to undergo the treatment usually employed for bringing it to the form of dry cakes. In this way those impurities which *soda* can dissolve, will be separated; but others, on which it has no action, will remain. For these Dr. Roxburgh, as well as M. de Cossigny, have recommended the application of a diluted sulphuric acid, which is said also to brighten the colour;* as indeed it might be

* Among the samples of indigo, with which I was favoured by Dr. Roxburgh, are three extracted from the *Guatamala* indigo plant, produced by seed, furnished by Colonel Kyd; and they are stated to have been made on three successive days, viz.

On the first, 104lbs. of leaves and shoots were cut at *sun-rise*, and by the usual process, they yielded six ounces $\frac{1}{277}$ of very beautiful indigo; i. e. at the rate of one ounce from about 17 lbs. of leaves and shoots.

On the second day, 64lbs. of leaves and shoots, also cut at sunrise, yielded in the same way, four ounces $\frac{1}{276}$ of very fine indigo, or at the rate of one ounce from less than 16lbs. of the leaves and twigs. This indigo was washed with diluted sulphuric acid, and three several times afterwards, with hot water; and though the produce was largest, the colour was a little the brightest.

On the third day, 56lbs. of the leaves and twigs were cut at *noon*, the sun having shone upon them several hours; they produced in

expected to do, in the way that the colour of indigo dissolved by it for the *Saxon blue*, is brightened. Probably the *diluted* acid, here recommended, will not be capable of diminishing the colouring matter of indigo, by dissolving and removing any part of it: but if there were any danger of this, it would be advisable to substitute the muriatic acid, which could have no such effect, upon the *indigo itself*, though it is equally efficacious in dissolving all other matters likely to be mixed with indigo. It is, however, doubtful, whether any considerable advantage would result from these applications: they could add nothing to the *tingent power* of the indigo, though they might improve its *appearance;* but even this could not be done without such a diminution of its weight, as would counterbalance the latter advantage, and in general dyers know how to avail themselves fully of the tingent particles of indigo, whatever extraneous matter it may contain.

Besides the several species of indigofera, already mentioned, and the Nerium tinctorium, (respecting which I must refer to Dr. Roxburgh's publication, in the xxviiith vol. of Transactions of the Society of Arts, &c.) there are several plants which possess the basis of indigo, though the characters of some of them have not been well ascertained. This latter observation, however, is not applica-

the same way three ounces $\frac{1}{299}$ of pure indigo; i. e. one ounce from about 19lbs. of leaves and twigs. This indigo was, I believe, intrinsically the best, but like that of the first day, was *not washed;* and the colour, though very beautiful, was in brightness a little inferior to that of the second day.

Considering that the leaves and shoots were cut at noon, on the third day, when the rays of the sun might be expected to cause an exhalation of much aqueous vapour, it is surprising that so little indigo was obtained.

ble to a plant lately found by Dr. Roxburgh, to afford indigo, and by him denominated indigofera cœrulea, (*carneeli* of the Telingas,) of which he has also given a minute description in the volume just mentioned; and from the leaves of which, says he, "I have often extracted a most beautiful light indigo."*

There is, moreover, a plant, belonging to a very different class, first mentioned as producing indigo, I believe by Mr. Marsden, in his History of Sumatra, p. 78, under the name of *taroom akkar.* He describes it "as a vine, or creeping plant, with leaves four or five inches long, *in shape like* (those of) *a laurel*, but finer, and of a dark green colour;" he adds, that "by reason of the largeness of the foliage, it yields a greater proportion of sediment." This plant Dr. Roxburgh considers as a species of *asclepias*, or swallow-wort, and has added to it the trivial or specific name of *tinctoria.* It appears to be nearly related to the nerium; both belonging to the natural order of *contortæ*, and both yielding their colourable matter from the leaves, most copiously, by hot water.† It was brought from Sumatra, and widely dis-

* I have now before me seven specimens of indigo, given to me by Dr. Roxburgh, and made by him from the indigofera cœrulea, with the help of *hot* water, to extract the *colourable* matter. They are similar to the same number of samples which the Doctor sent in 1793, with a description of the plant, to Mr. Ross, at Madras, to be forwarded to the Court of Directors of the India Company, and are all very fine blue or violet indigo; particularly four of the seven, which in appearance and effect, are, in my judgment, equal to the finest flora of Guatamala.

† Dr. Roxburgh has favoured me with three samples of indigo, which he obtained from the asclepias tinctoria, by hot water; one is a very fine violet-coloured indigo; another is more inclined to blue; and the third to purple; the two last were specifically a little heavier than the first; the worst of them, however, would, I think, be considered as worth 8*s.* per pound.

tributed in Bengal, about the year 1791; is perennial, and easily propagated by layers, slips, or cuttings. I mention these particulars, because I shall have occasion to refer to them presently, in regard to a substance denominated barasat verte.

Professor Thomas Martyn, mentions the galega tinctoria, as being the plant from which the inhabitants of Ceylon prepare their indigo, which yields a *pale* blue dye (see his edition of Millar's Gardener's Dictionary.) He also mentions, on the respectable authority of Loureiro, that the spilanthus tinctoria is cultivated in China, and Cochinchina; that the leaves bruised, yield a most excellent blue colour, and a green, prepared by a method more easy than from indigo, and not inferior in brightness.

Linnæus says, the Swedes obtain a blue colour from the scabiosa succisa, by treating it like the isatis tinctoria, or woad plant; and I have been informed, that the cheiranthus fenestralis, or cluster-leaved stock gillyflower, is also capable of yielding indigo. This may be easily ascertained.

Besides plants of the genus of indigofera in Africa, we have reason to believe there are several belonging to other genera, capable of producing indigo. Dr. Winterbottom says, "there is now no room to question that the blue dye, commonly used by the natives of the *windward coast*, is not indigo, but is obtained from a very different plant." He adds, "a few roots of it, I am informed, have lately been planted within the settlement (of Sierra Leone,) so that an accurate description of it may soon be hoped for." Probably, this is the plant to which Professor Afzelius alluded, when, upon his return from Sierra Leone some years ago, he told me he had discovered a new plant producing indigo, of which he intended soon to publish a description. Dr. Winter-

bottom also states, on the authority of M. Isart, (Reise nach Guinea) that on the gold coast, the negroes, instead of the indigo plant, infuse " the leaves of a species of bignonia, and the root of a species of tabernæmontana, with a lye of wood ashes, to dye cotton blue." See his account of the Native Africans, vol. i. p. 97. The amorpha fruticosa, and the sophora tinctoria, Lin. also afford coarse sorts of indigo.

This production often differs greatly in regard to its specific gravity, some indigo being lighter than water; and the lightest being always, and justly, the most esteemed; because it is always the purest, excepting only when the comparative weight has been increased, by very *forcible pressure*, to separate the water, and accelerate the drying, that it may not be in danger of becoming mouldy.* Indigo is sometimes adulterated, by fraudulently adding to it various gummy, resinous, earthy, and mucilaginous matters, and particularly an extract from the fruit of the embryopteris glutinifera, denominated *gaub* in the East Indies. It is also rendered both heavier and less pure, by employing lime too copiously, as a precipitant, which not only subsides, mixed with the indigo, but also throws down many other useless matters. This also happens in a greater or lesser degree with other precipitants, when used in excess, and more especially with alum.

Indigo also differs in regard to its colour, e. g. the Guatamala, which has long been the most esteemed of

* Quatremere Dijonville asserts, and I believe truly, that indigo closely packed, and secluded from atmospheric air, will soon become hot, and undergo some degree of fermentation, by which white specks will be formed within the cakes of indigo. See his " Analyse et examen Chemique de l'Indigo, &c." Mém. des sçav. etrang. tom. ix. Indigo in drying should always be shaded from the sun, and a free current of air be made to pass over it.

all the varieties of American indigo, is divided into three sorts; of which the first, called by the Spaniards *flora*, has a very fine blue colour; the second, which bears the name *sobré salliente*, is violet; and the third, named *corti-color*, is copper-coloured. When the first of these is sold at 9*s*. the pound, the second is commonly thought to be worth 7*s*. and the third 5*s*. 6*d*. Of the East Indian indigo, that of Java was formerly most esteemed, but since the manufacture of this commodity has so much engaged the attention of the British inhabitants in that part of the world, indigo superior even to that of Guatamala, has been imported, in considerable quantities, from the British possessions there: And of this, the finest blue commonly sells 20 per cent. higher even than the finest glowing purple, (though the last probably contains nearly as much colouring matter as the first,) and 70 or 80 per cent. higher than the best copper-coloured. The price has, I believe, also, been sometimes affected in this country, by the size and form of the indigo cakes; the large and square selling for more than those which are flat and thin, and these last for more than broken indigo, though it must all be broken and powdered, before it can be advantageously used.

M. Berthollet has proposed to ascertain the comparative values of different parcels of indigo, by dissolving equal portions of each in sulphuric acid, and afterwards destroying their colour by adding the oxymuriatic acid to them, severally; always considering that indigo as most valuable, which requires the greatest portion of oxymuriatic acid for the extinction of its colour. But probably the relative quantity, and value of colouring matter, in any parcel of indigo, might be as well measured, or ascertained, without employing the oxymuriatic acid, by mixing a certain portion of the indigo,

when dissolved by sulphuric acid, with a certain quantity of water in a glass, and comparing the depth, or fullness of its colour, with that of other indigo treated in the same way, and taken as a standard or point of comparison. But, after all, there will be so much inequality in the different pieces or cakes of indigo, as it is commonly assorted, in any one package, that considerable uncertainty must attend any method of ascertaining its true value, by trials with small parts or samples only.

The most accurate analysis of indigo, with which I am acquainted, is that recently made by M. Chevreuil. He took for this analysis the best Guatamala indigo, and found that by *digestion in hot water*, it yielded to the latter, ammonia, indigo at the minimum of oxidation* combined with ammonia, a particular green matter, in union with ammonia, gum, and a small quantity of yellow extractive matter; amounting all together to 12 parts for every 100 of the indigo employed. From the

* What is here called indigo at the minimum of oxidation, ought to be rather considered as the *basis* of indigo; for while it is susceptible of dissolution, either by water, or alcohol *alone*, it does not possess the properties, nor strictly deserve the name of indigo, though capable of acquiring the former, and deserving the latter, by a sufficient addition of oxygene. The existence of this basis, or of indigo at the minimum of oxidation, in the best Guatamala indigo, proves the difficulty of thoroughly combining the former, with its *full porportion* of oxygene by the usual process; and if it be thus contained in Guatamala indigo, how much more of it will have been left suspended and lost in the beating vat, as commonly managed? M. Berthollet mentions, probably from personal observation, that in Egypt, the indigo-making process is so badly conducted, that the indigo produced by it, is always *greenish*, (" verdatre") and gives a bad colour; and that it is so much disposed to dissolve by fermentation, that the dyers need only mix a little *brown* sugar with it in the vat, to excite one, sufficient to render it fit for dyeing. An effect which could only result from a deficient oxygenation. See Elements, &c. tom. ii. p. 41.

remaining 88 parts he obtained by digestion with alcohol, 30 parts, consisting of a green matter, a reddish resin, and a little indigo. By digesting the residuum with muriatic acid, he obtained 6 parts of "*resine rouge*," 2 parts of carbonate of iron, and 2 parts of red oxide of iron, in union with alumine; after these had been all separated, there remained about three parts of siliceous earth, and 45 parts of *pure indigo*. This last, but no other part, was capable, when burning, of emitting that *beautiful purple smoke*, by which indigo is peculiarly distinguishable; and which consists of indigo, rendered volatile by heat, without any decomposition. He concluded from this analysis, and from other experiments, that indigo may be purified "par la voie seche,* et par la voie humide;" that when purified, it is susceptible of volatilization and crystallization: and that, when most purified, its colour is *purple*, rather than *blue*. (See Ann. de Chimie, tom. 68.) I think it probable, however, that this purple appearance results from a greater condensation of the colouring matter of indigo; since that of Prussian blue, when most pure, exhibits a similar purple coppery aspect.

Bergman after separating, as far as he was able, the extraneous matters mixed with indigo, found that 100 parts of it left 47, which he considered as its colouring matter, very nearly in a state of purity; and this being

* The pure part of indigo may be all converted to vapour, without any decomposition, by an elevation of temperature, a little *below* the point at which it would be decomposed, *and the simultaneous* application to its surface, of *a current* of any elastic fluid, which exerts no chemical affinity upon the indigo. This, however, will be most advantageously performed, with but small quantities of indigo; for in larger, it will suffer a *partial* decomposition, if kept for any considerable time at such a temperature as is necessary to render it volatile.

carefully distilled by itself, yielded 2 parts of carbonic acid, 8 of an alkaline liquor, 9 of an empyreumatic oil, and 23 of charcoal; which last, being burnt in the open air, left 4 parts, of which about one half was an oxide of iron, and the remainder a fine siliceous powder.

Bergman supposed the *blue* colour of indigo, to result from a combination of iron with the colouring matter of the plant, as the colour of ink does from the union of that metal with the colouring matter of galls, and that of Prussian blue from its union with the prussic acid. But these supposed analogies are without any foundation; for the proportion of iron is not only by much too small to produce such an effect, but it possesses no affinity for the basis of indigo, nor the least power of influencing, or contributing to its colour.

M. de Chaptal, (who as a minister and a chemist, has manifested a great superiority of intellect, and of science,) appears to think, that in the fermentation of indigo, charcoal greatly contributes to produce its blue colour; "la dissolution des vegetaux, (says he,) donne un charbon d'un tres beau bleu, et il est probable, qui lorsque la couleur bleu est develloppée par la fermentation, le carbone est presque mis a *nu*, et qu'il reste en combinaison avec une huile, qui ajoute a la fixité de la couleur, et indique le dissolvant le plus convenable." (Chim. appl. aux Arts, tom. ii. p. 406.) But if this reasoning were just, why is it that so few vegetables can be made to produce indigo, though all of them contain the basis of charcoal; and what becomes of the supposed charcoal, when by depriving indigo of its oxygene, in the way which will be hereafter explained, the basis of it, dissolved and secluded from atmospheric air, is rendered *colourless*, and *pellucid*, until by the re-admission of oxygene, its colour is reproduced? Certainly there is no instance in which charcoal has

been rendered colourless by an abstraction of oxygene, and afterwards black, by the re-union of it. Probably, the only similitude between charcoal and indigo, is that which I formerly pointed out; i. e. that in each, the basis combines with oxygene, and thereby acquires colour and stability; with a complete *indissolubility* in the former, and a very difficult solubility in the latter. But as their bases are different, so are their respective colours, and several of their other properties.

The colouring matter of all sorts of indigo, is nearly the same, and capable of giving nearly similar shades of colour, when the basis has been sufficiently, but not excessively oxygenated. The impure or extraneous matters, mixed with it either unavoidably, or fraudulently, are many and various; and they may be generally dissolved or separated, by the means employed by M. Chevreuil; but when this has been done, there are very few chemical agents, capable of acting upon the residual pure colouring matter of indigo, duly constituted. There is, indeed, but *one* way, in which it can be dissolved, without injuring its basis, and diminishing the stability of its colouring matter; and this is, not by any *single* agent, but by the *co-operation* of several: of these, the first are such as by possessing a greater affinity for oxygene, than that which is exerted by the basis of indigo, are enabled to *deoxygenate* the latter, or at least deprive it of a great portion of its oxygene, so as afterwards to render it soluble, by means which otherwise would be incapable of acting upon it; particularly lime, and the several alkalies, in their caustic state.

The matters employed to deprive indigo of its oxygene, and thereby render it soluble, are either vegetable, animal, or mineral. The vegetable are chiefly such as excite, or promote, fermentation; and indigo seems to

have been exclusively employed with these, for some time after it was first made known, for dyeing in Europe. Until that period, blue colours had only been dyed by the woad, as I have already mentioned; and it being erroneously believed, that the colours of indigo, if employed *by itself*, would prove fugitive, it was in some countries totally prohibited, in others only permitted to be used when mixed with about one hundred times its weight of woad, in what was called the woad-vat. This was, and continued to be, the case in France, even under the enlightened administration of Colbert, and afterwards until the year 1737; when, in consequence of the experiments and representations of M. Dufay, a new regulation was issued by the French government, permitting the dyers to employ indigo either alone, or with woad, at their option. The preparation of the woad-vat, under the name of Cuve de Pastel, was minutely described by Hellot, (Art de la Teinture, chap. 10,) as it has been since, more correctly, by Quatremere, Berthollet, Chaptal, and others; it is, besides, so well known to practical dyers, that a particular account of it from me cannot be wanted by them, and it would be superfluous to my *other* readers, who need only to be informed, that the woad is brought to ferment by first pouring over it a boiling decoction of weld, madder, and bran, and by keeping it afterwards in a suitable temperature, until blue veins appear on the surface of the liquor. Quick lime is then added to it, and also the proper quantity of indigo, finely ground with a small portion of water; the mixture is then well stirred, and afterwards covered over; and such other means are employed as may be necessary to keep up the proper, and only the proper, degree of warmth and fermentation, until a sufficient *deoxygenation*, and solution of the indigo, has taken place, which may be

known by the blue or shining coppery colour of the liquor on its surface, (where the indigo is constantly revived by an absorption of oxygene), and by its *green tint* every where below the surface. With these appearances, the liquor will be fit for dyeing, and though the colour which it gives to wool or cloth will be *green*, when first taken out of the dyeing liquor, it will very speedily become blue, when exposed to the air, by attracting and regaining the oxygene taken from it during the fermenting process; the abstraction of which was the cause of its green colour.

It has hitherto been found extremely difficult to attain the proper, and only the proper, degree of fermentation, in conducting the woad-vat; and this difficulty seems to have resulted principally from the *ever varying properties* of the woad, as it has been commonly and ignorantly prepared. Indeed, there is good reason to believe, that it would be much better if the manufacturers of this article would wholly abstain from giving it any sort of fermentation, (*which at best is certainly unnecessary*), and content themselves with barely grinding the plant, and drying it as expeditiously as possible, forming it into balls at the proper time. Much also depends upon the quantity of lime employed; not only for the purpose of dissolving the indigo, but also for that of moderating the fermentation; which, when excessive, induces a putrefactive process, and destroys the tingent power both of the isatis and indigo. Too much lime, on the contrary, obstructs the necessary degree of fermentation; the colour of the liquor then becomes blackish, and the vat remains useless, until the obstacle has been overcome, by the addition of matters suited to counteract this excess. This vat, or preparation of indigo and woad, is very generally employed for dyeing wool and woollen cloth or stuffs.

Indigo is moreover dissolved, without any admixture of woad, in a vat which Hequet d'Orval et Ribaucourt, Berthollet, and others, have described under the name of Cuve d'Inde, or Indigo-vat; and which is also well known. For this the indigo being ground with a little water, its deoxygenation is produced by bran and madder, (acting as vegetable ferments,) and its dissolution by potash. This is liable to fewer failures than the former vat, but it is more costly, and is chiefly employed to dye silk. When fit for use, the surface of the liquor exhibits a blue scum, intermixed with patches of a shining coppery colour, and the mass below the surface appears of a fine green.

The only vat in which animal matters are made to co-operate in the deoxygenation of indigo, is that with urine, now but little used, except as a domestic dye for small woollen articles; madder, or some other vegetable ferment, is commonly added to assist in abstracting the oxygene, and when this is done, the ammonia, or volatile alkali, of the urine, produces a dissolution of the indigo.

The influence of *mineral* agents in the deoxygenation of indigo, is yet more obvious and interesting than that of animal or vegetable ferments; and the former are, therefore, advantageously employed by dyers and calico printers, in fixing the colour of indigo upon linen and cotton. Of these the principal is the oxide of iron, *at a low degree of oxygenation*, as it exists in the sulphate of that metal. Dr. Priestley appears to have first noticed the powerful attraction exerted by this sulphate, or by the oxide recently precipitated from a solution of it, upon the oxygene of the atmosphere, though its use, in promoting the dissolution of indigo, had been previously discovered by dyers, but without their having had any suspicion of its mode of action.

Indigo moistened, and finely ground, being put into warm water, with twice its weight of sulphate of iron, and the same quantity (as the latter) of pure lime, recently and well burnt, will, with a little stirring, be dissolved in twenty-four hours. In this mixture, a part of the lime unites with the sulphuric acid, forming calcareous sulphate, or selenite, and at the same time precipitates the oxide of iron, which, not being saturated with oxygene, attracts so much of that which was combined with the indigo, as to render this last soluble by the lime in excess, above that which was required to saturate the sulphuric acid. The beginning dissolution of the indigo, may be perceived by a shining copper-coloured pellicle, which forms itself on the surface of the mixture, while the liquor itself becomes green, and afterwards gradually inclines more and more to the yellow, as the solution advances. When it is completed, and the liquor settled, the cotton yarn or stuffs are to be dyed in it: they appear yellow when first taken out, but by absorbing the oxygene, will rapidly assume and pass through the different shades of green, and in a few minutes become blue; the oxygene regenerating the indigo, in the pores of the cotton.

Mr. Haussman, of Colmar, in Alsace, who, with a considerable stock of chemical knowledge, daily practices the arts of dyeing and calico printing, published an excellent "Memoire sur l'indigo, et ses dissolvans," in the Journal de Physique, &c. for March, 1788, in which he observes, that the change of colour from yellow to blue, in cottons dyed as before mentioned, may be greatly accelerated, and the blue rendered deeper and brighter than it would otherwise become, by plunging the dyed cottons, when first taken out of the vat, into water soured by vitriolic acid, which hastens the regeneration of the indigo, and moreover dissolves and

carries off a portion of white calcareous sulphate, or selenite, which would otherwise diminish the intensity of the blue colour.

If the colour of the vat be not all used, soon after it has been prepared, it will require occasional stirring, since the dissolved indigo, by continually absorbing oxygenous gas from the atmosphere, will be constantly revived upon the surface of the liquor; and, when so revived, it can only be re-dissolved, by being again subjected to the combined action of lime, and oxide of iron: if by length of time these should become perfectly saturated with oxygene, and carbonic acid, before the blue colour is all used, a farther portion of each must be added, and somewhat more of lime than of the sulphate of iron.

It must be observed, that where lime is the *only solvent* of indigo, as in the vat last described, the colour is not sufficiently condensed for dyeing very deep blues; and, therefore, when these are wanted, it is found best to increase the power of the lime by an addition of potash, or vegetable alkali, not exceeding in weight twice the weight of the indigo to be dissolved.

In calico printing, when different shades of blue are to be produced in the same piece, the indigo finely ground with sulphate of iron, and properly thickened, is first printed on the calico, which after drying, is put alternately into lime water, and then into a solution of sulphate of iron, in different vats, until by these means a sufficient abstraction of oxygene is made by the latter, and a sufficient dissolution of the indigo by the former, to fix the colour permanently. This is called China blue, and M. Chaptal mentions it as an instance in which the colour is applied before the mordant. But it seems to me that there is no *mordant* in this operation, which has for its object, *nothing but a dissolution of*

the indigo, which being dissolved, fixes itself by simple application.

Mr. Haussman observes, that all the precipitates of iron, whether obtained from solutions of that metal by the mineral, vegetable, or animal acids, will serve, with quick lime, to dissolve indigo, as well as that of green vitriol, provided, and so long as they retain the property of absorbing vital air; but that a nitric solution of iron, or the rust of it, or any other preparation, where it exists in an ochrous form, not attracted by the magnet, nor capable of attracting pure air, will be wholly useless towards producing a dissolution of indigo, even though employed with an excess of quick lime, or of caustic alkali.

Mr. Haussman further observes, that caustic alkali, with fine iron filings, instead of the precipitate from copperas, would not dissolve indigo; but that (regulus of) antimony, brought into the form of a powder, dissolved it perfectly with the caustic alkali, or quick lime slacked by water; though the calces, or oxides of antimony, in this way, produced no such effect: nor did any precipitates of copper: on the contrary, they all seemed rather to hasten the regeneration of indigo, after it had been dissolved by some other means. This effect of the oxides of copper, (which results from the great facility with which they relinquish their oxygene) is now well known, and calico printers avail themselves of it in making what are called *reserves*, or applications of verdigrise, sulphate of copper, or tobacco-pipe clay, and glue, or in its stead, tallow, mixed and printed upon particular parts, intended to be hindered from imbibing the indigo blue, and kept *white*, while the rest of the piece is dyed. After mentioning this effect, it can hardly be necessary to add, that when the sulphate of iron is want-

ed to *deoxygenate* indigo, care should be taken that it be not mixed with any oxide of copper.

I have repeated most of Mr. Haussman's experiments, with different precipitates, or oxides of iron, and with effects nearly similar to those he describes. I found that neither the rust of iron, nor the nitric oxide of it, would assist in the dissolution of indigo; obviously because they were both already saturated with oxygene: I also found, that even the oxide precipitated from sulphate of iron, failed, and for the same reason, when, instead of separating it by lime, it was obtained by dissolving the sulphate in water, and leaving it for some weeks exposed to the air in warm weather, where the iron was farther acted upon, and saturated, as well as precipitated, by the oxygene which it gained from the atmosphere.

It is upon the same principle, that the *topical* indigo blue, employed by calico printers, chiefly with the pencil, is made, only substituting for the sulphate of iron, a portion of red* orpiment, (sulfure of arsenic), which has a similar power, when dissolved by an alkali, of depriving indigo of its oxygene, and thus rendering it soluble. The ingredients of this composition are by different persons, mixed in different proportions, and

* *Red* orpiment produces a better effect than the *yellow*, because it contains less oxygene. The *fact* was known long before the *cause*. Until lately it was supposed, that the red and yellow differed only by containing different proportions of sulphur; and that this difference enabled one to act more efficaciously than the other, in the deoxygenation of indigo; but this is not true. When orpiment is employed in this way, the alkali precipitates the arsenic in its *metallic* form, depriving it, at the same time, of a part of its sulphur. After which, the metallic arsenic acts upon the indigo, in the same way as the oxide of iron does, when green vitriol is employed, and by sufficiently abstracting the oxygene of the indigo, enables the caustic alkali to dissolve the latter.

will succeed with considerable latitude in this respect; indeed, the variable qualities of indigo, render it difficult to prescribe any exact proportions, which shall be always equally efficacious.

Mr. Haussman mixes twenty-five gallons of water, with sixteen pounds of indigo, well ground, (or a greater or smaller quantity, according to the quality of the indigo, and the depth of colour wanted), to which he adds thirty pounds of good carbonate of potash, placing the whole over a fire; and as soon as the mixture begins to boil, he adds, by a little at a time, twelve pounds of quick lime, to render the alkali caustic, by absorbing its carbonic acid. This being done, twelve pounds of red orpiment are also added to the mixture, which is then stirred, and left to boil for some little time, that the indigo may be perfectly dissolved; which may be known by its giving a yellow colour, immediately upon being applied to a piece of white transparent glass. M. Oberkampf, proprietor of the celebrated manufactory at Jouy, near Versailles, uses a third more of indigo; and others use different proportions, not only of indigo, but of lime, potash, and orpiment; which all seem to answer with nearly equal success; but with the best violet-coloured Guatamala indigo, it is certain that a good blue may be obtained from a less quantity than that prescribed by Mr. Haussman, by using as much recently burnt pure lime, as of indigo, the same quantity of orpiment, and twice as much potash. This composition is to be thickened by gum, which should be dissolved in it whilst hot; and it should afterwards be kept secluded as much as possible from the access of atmospheric air.

Indigo dissolved in this way, for penciling or printing, I shall hereafter call *topical blue*—its strong tendency to attract oxygene from the atmosphere, and to be

thereby regenerated, renders its use subject to many difficulties; it being almost impossible to pencil, and more so to print therewith, a piece of cotton throughout of the same shade, whatever pains may be taken to apply it equally, and quickly, by the most expert and careful hands.* It will give a fast colour, only so long as it continues yellow, or, at most, of a yellowish green; as soon as it appears blue, the indigo may be considered as revived, and incapable of fixing itself on the cotton: in this case, however, it may be redissolved, by adding more caustic alkali and orpiment. The clear liquor only, when gummed, is to be used; but it is not to be separated from the sediment, which helps to preserve it in a state of dissolution.†

* Being at Manchester in 1795, Messrs. Hoyle and Son, showed me in confidence, a method, of their invention, for printing calico, with the *topical* blue, expeditiously and successfully, by employing cylindrical rollers, and feeding them with the blue, through small perforations made at the *bottom* of a close receptable for it, placed immediately over the upper roller, and extending the whole width of the calico, to which the colour was applied before it could have time to absorb oxygene. I believe this invention is now known to others, and that I may therefore mention it without any breach of confidence.

† I cannot discover when, or by whom, orpiment was first employed to promote the dissolution of indigo. In some MSS. with the perusal of which I was lately favoured, and which appear to have belonged to the late Dr. Lewis, author of the Philosophical Commerce of Arts, and to contain some of the materials employed in that work, I find it noted, in what I consider as the Doctor's handwriting, and under the date of 1734, that certain *linen* printers (calico being then but little employed in that way) had offered to give him one hundred guineas if he could "find out a way to print blue;" and that the writer agreed to attempt the discovery, if these printers would make him acquainted with the best means known to themselves of doing this, which they did, and their composition is stated to have consisted of equal parts of indigo, and quick lime, with half as much copperas, (green vitriol), and twice as much

In making the before-mentioned composition, a copper-coloured pellicle appears on the surface of the liquor as soon as the indigo begins to dissolve; and this pellicle becomes violet, and at last blue, by longer exposure to the atmosphere. Mr. Haussman observes, that the same pellicle arises, with the same appearances, if the solution of indigo be put into contact with pure vital air; but that, under the receiver of a pneumatic machine, it diminishes in proportion as a vacuum is produced; and that, as might be expected, it does not appear at all, in either hydrogene, or nitrogene. He farther observes, that if, instead of orpiment, the sulphur and white arsenic, of which it is formed, be employed, together or separately, with quick lime and potash, no solution of indigo will take place; and this will also happen, even where orpiment is used, if quick lime be not employed to render the alkali caustic. That having put indigo, dissolved by orpiment, lime, and potash, into contact with oxygene gas, obtained by distillation from nitre, he soon found that excepting a little nitrogene mixed with it, the whole had been absorbed by the solution of indigo, and the blue rendered unfit for use, the indigo being regenerated. In this instance, he also found that a part of the alkali remained caustic, while another part of it had combined with the vitriolic (sulphuric) acid,

pearl ash. I conclude from this, that the use of orpiment, for the purpose under consideration, was then unknown, at least in this country, though sulphate of iron was employed, but in a proportion by much too small to produce its *best* effect. I find afterwards, an account of several experiments made by the writer, to accomplish what was desired of him by the linen printers, but the means employed by him for this purpose, were more likely to impede, than co-operate in the dissolution of indigo. So little was the subject then understood, that all reasoning upon it tended rather to mislead the reasoner, than conduct him to the truth.

(formed by the union of the sulphur to a part of the absorbed oxygene) and thereby produced sulphate of potash; another part of the oxygene, so absorbed, had combined with the arsenic, and changed its metallic form to that of an oxide, in which state it had united to the caustic alkali; and the rest of the absorbed oxygene had combined with, and regenerated the dissolved indigo.

Mr. Haussman was indeed inclined to explain the solution of indigo, according to the phlogistic system, by considering it as resulting from a greater affinity which phlogiston was supposed to have with indigo than with arsenic, and that it was the action of this phlogiston, joined to that of the caustic alkali, which operated the dissolution in question; but that the phlogiston, having still a greater affinity with dephlogisticated (or vital) air than with indigo, abandoned the latter as soon as the former was presented to it, leaving the indigo in its regenerated form; the alkali alone not being sufficient to preserve it in a state of solution. But a much happier, and more natural explanation of these effects, is afforded by the new doctrine, as already stated; and it is strongly supported by all that we know of the nature of indigo, and the properties of those agents which are employed to dissolve it.

Mr. Haussman found that the sulphuret of antimony (crude antimony) assisted in dissolving the indigo, for topical blue, as well as orpiment, but that it was unfit for penciling or printing, because the antimony being precipitated, in the form of a mineral kermes or golden sulphur, tarnished the blue colour, and adhered to the linens or cottons almost as strongly as the indigo itself; an inconvenience which I have also experienced. The oxide of antimony, with sulphur, did not produce a solution of the indigo, when used instead of the crude

antimony; though antimony, in its metallic state, (i. e. the regulus) reduced to powder, had occasioned the dissolution of indigo in the same way, and as well as the crude antimony. He found, however, that no such effect was produced by the filings of zinc; though when heated, this metal has great affinity with oxygene. He attempted in vain, to dissolve indigo, by a combination of sulphur with the other metals; and he attributes his want of success to the circumstance of their being dissolved with difficulty, or perhaps not at all, "par la voie humide," in the caustic alkalies.

Besides repeating a great part of these experiments, and with nearly similar effects, I have made some, which, probably, were not attempted before; and several of them produced effects highly deserving of notice.

Having in 1791, attempted unsuccessfully to dissolve pure blue Guatamala indigo, finely powdered, by long and repeated boilings in water, with an excessive proportion of shell-lime taken hot from the fire, and afterwards by renewed boilings with a copious addition of potash, I thought it might be worth while to try the oxide of tin, which had then, I believe, never been employed to promote the dissolution of indigo. It so happened that I had at hand nearly a pound of an oxide of tin, prepared some time before, (for a different purpose), by putting two pounds of common single aqua fortis, diluted with as much water, upon a quantity of tin, not in very small pieces, and leaving the former to act slowly upon the latter during several months, until all its oxygene was exhausted; after which, I found the oxide, or calx, formed into lumps, and settled at the bottom. The clear liquor being decanted from the oxide of tin, the latter was slightly rinced with water, and being dried, remained in solid lumps. Some of these, weighing about twice as much as the indigo which I had

found it impossible to dissolve, by the means just mentioned, were put into the caustic alkaline liquor, and in less than five minutes I perceived signs of a beginning dissolution, which increased rapidly, until the liquor had passed through all the shades of green, and become yellow, except at its surface, which was covered by a fine copper-coloured pellicle, of a shining metallic appearance. Silk and cotton dipped into the liquor, were taken out yellow, but quickly became green, then assumed a shining copper-colour, which afterwards changed to violet, and finally to a deep blue; which was found, by washing, to be permanently dyed. Part of the same liquor, gummed, and applied topically, answered as well for penciling as any topical blue I ever saw. Another part of it, being poured into a white glass phial, so as, with a portion of the lime and oxide of tin, to fill it completely, (without gum), and being well stopped and left at rest, the mixture *in a few days became as pellucid and colourless as clean water*, excepting only the sediment at bottom.* Upon unstopping the phial, the *surface* of the liquor, by coming into contact with the atmosphere, and absorbing oxygene, instantly became first green, and then blue; and upon re-stopping the phial, and shaking it, the indigo forming this blue surface was dispersed through the mass of liquor, and tinged it of a beautiful greenish yellow; but there being

* I have, at p. 126, stated the basis of indigo to be *colourless*, when *wholly* deprived of oxygene, and of this, the fact just mentioned is a sufficient proof. Dr. Roxburgh has indeed said, p. 287, that "the indigo base is *naturally green*, while it remains dissolved in its watery menstruum, by which it was extracted from the leaves." In regard to this, however, I will only observe, that *wherever* the basis of indigo exhibits a *green* colour, it must be combined with a portion of oxygene, and this portion must be greater than that with which it is united in the yellow solution made for giving blue by *topical* application.

a sufficient quantity of oxide of tin unsaturated, the oxygene was soon absorbed, and the liquor again rendered colourless.*

When, instead of the oxide of tin, I employed the metal finely granulated, it produced no effect towards dissolving indigo; and on trying tin, which had been calcined with saltpetre in a crucible, I found that it not only did not dissolve the indigo itself, but prevented it from being dissolved by the oxide of tin (produced by the aqua fortis, as just mentioned,) or by crude antimony, or sulphate of iron, either singly or combined; indeed it was with difficulty dissolved, when orpiment, in a large proportion, was added afterwards; this I also found to be the case of tin, calcined alone in a crucible by strong heat: bismuth calcined in like manner, equally obstructed the solution of indigo. Probably in these cases the metals so calcined not only did not attract the oxygene of indigo, but let go some of that which they had imbibed during calcination.

In the course of my experiments upon indigo, I was induced to make trial of a large proportion of refined sugar, (instead of orpiment), and I found that it acted efficaciously in dissolving indigo, with the usual appearances, and producing a topical substantive blue, as permanent, and every way as good as any in use. I afterwards tried coarse brown sugar, and I found it at least as effectual as the refined, for this purpose; it then occurred to me, that this might be a valuable substitute

* Berthollet, tom. ii. p. 57, after mentioning my discovery of the use of the oxide of tin in promoting the dissolution of indigo, adds, "On peut dissoudre immediatement l'etain peu oxidé, dans la potasse, et faire agir cette dissolution sur l'indigo: elle produit promptment une cuve ou les toiles se teignent en *bleu tres intense*." The formation of such a vat was naturally suggested, by the knowledge of what I had published on the subject.

for orpiment, the use of which, as a constituent part of the topical blue, may, from its poisonous quality, sometimes produce mischief, and always gives the composition an unpleasant smell. I moreover conceived, that, by employing a large proportion of brown sugar, it might be practicable to thicken the mixture sufficiently for penciling or printing, and thereby avoid the greater expense of gum for that purpose; and upon trial, this also proved to be the case, the sugar thickening the solution sufficiently, and afterwards drying as expeditiously as when thickened by gum, contrary to what I had apprehended as probable, from recollecting that ink, when thickened by sugar, was disposed to retain moisture, and dry very slowly. I think, moreover, that when the solution of indigo is both made and thickened by brown sugar, in this large proportion, the latter, by being able to absorb a larger quantity of oxygene from time to time, enables the topical blue to bear exposure to the atmosphere somewhat longer, without a regeneration of the indigo, than when it is dissolved by only the usual proportion of orpiment. I conclude, therefore, that this way of composing a substantial topical blue, by employing coarse brown sugar instead of orpiment and gum, is deserving of particular attention, as forming a composition free from all poisonous qualities, and at the same time cheaper and better than that generally used. Molasses will serve as well as brown sugar to promote the dissolution of indigo; but I think not so well to supply the place of gum in thickening the composition.*

* Since the former edition of this volume, I find that, according to Professor Pallas, the blue dyers of Astracan dissolve indigo, by boiling it in a lixivium of soda, with quick-lime and clarified honey; which last appears to act like sugar in the deoxygenation of indigo. Dried raisins and figs, I have observed to produce a

Sugar used in this way, seems to act like orpiment in combining with oxygene; which it is strongly disposed to do in other circumstances. M. Berthollet, in the second volume of the Annales de Chimie, mentions, that, in distilling the sulphuric acid upon different animal and vegetable substances, he found none of them so proper as sugar to form a large quantity of sulphureous acid; which it could only produce by its great affinity with oxygene.

I found, upon different trials, that, with the help of potash and lime, I could not dissolve indigo, either by sulphur, or white arsenic, or charcoal, or oxide of bismuth, or of lead (minium), or of zinc (lapis calaminaris,) or of manganese, or the alkaline solution of flints, or of the earth of alum, or by magnesia. I was equally unsuccessful with copper, in all the ordinary preparations of it: and indeed when verdigrise was added to indigo mixed with lime and potash as usual,—there was not only no solution, but the verdigrise afterwards obstructed the action of all other agents upon it, insomuch that the

similar effect. Probably the most useful and inoffensive topical blue may be made by boiling powdered indigo with three times its weight of coarse brown sugar, in a caustic lixivium of soda and potash, and assisting the deoxygenation by adding the oxide of tin precipitated by lime from a solution of that metal by muriatic acid. If a muriate of tin be added to the topical blue, prepared with caustic alkali and red orpiment, or with caustic alkali and sugar, it will occasion a considerable effervescence, and at the same time produce a farther deoxygenation of the indigo, and thereby render the previous *greenish yellow* colour of the mixture almost white, and make the effervescing froth appear almost of the colour of milk, though even this froth, if speedily applied to calico, will attach itself, and by regaining oxygene, stain it with a permanent blue colour. Such an effervescence, however, is inconvenient, and I only mention the fact as an additional illustration of the theory before stated.

indigo remained undissolved, notwithstanding the combined action of crude antimony, orpiment, oxide of tin, sulphate of iron, and sugar, which were added in large doses, any one of which, with the quick-lime and potash, would have effectually dissolved the indigo, had there been no verdigrise or oxide of copper in contact with it. The sulphate of zinc (white vitriol) was almost as adverse to the dissolution of indigo; for it not only did not contribute thereto, with potash and lime, but it hindered a solution from taking place, by the oxide of tin, crude antimony, sugar, and sulphate of iron, applied one after the other: though when to all these, a large portion of orpiment was added, and the mixture kept some time in a boiling heat, the indigo did at length dissolve, but with great difficulty and tardiness. The red sulphuret of mercury I found, on repeated trials, incapable of contributing, in any degree, to dissolve indigo with lime and potash; though it did not obstruct the dissolution thereof, when orpiment was added.

Wishing to know what effects would result from a stronger action of potash, lime, and orpiment, upon indigo, I dissolved it with three times the usual portion of these agents, and having afterwards shaken the whole mixture well together, I filled a large transparent glass phial therewith (but without any gum,) and having secured it from all contact with external air, by a glass stopper covered with wax, I left it in that state for three months, shaking the phial occasionally, that the more fluid part of the mixture (which had become colourless) might be acted upon more equally by the lime, &c. at bottom; after which, the phial being opened, I found that the mixture (which with different proportions, had always given a deep permanent blue to cotton,) was become incapable of manifesting any colour by the contact of

atmospheric air; the indigo having been not only deprived of the oxygene necessary to its colour, but probably rendered incapable of re-uniting with it as formerly, in consequence of a decomposition of its vegetable basis, or a new combination thereof, with one or more of the agents in question, too intimate to be overcome by any of the usual means of regenerating indigo. Here we have an instance of one of the most permanent of colouring matters losing its colour irrecoverably; not by any thing like *combustion*, which necessarily requires the presence and combination of vital air, but by means which seclude it from, and deprive it of, all such air.

The topical blue, when made, is often applied by the pencil upon spots or figures previously dyed yellow, in order to produce a permanent green: but the caustic alkali contained in it, especially when employed too freely, seems to weaken the yellow on which it is laid. Wishing to remove this difficulty, I thought of neutralizing the alkali, at least in some degree, so as to make it harmless in this respect, without, at the same time, rendering the blue less efficacious. For this purpose I selected the muriatic acid principally, because as no oxygene had ever been ascertained to exist, as one of its constituent principles, there seemed to be no danger of its reviving the indigo, by imparting oxygene to the topical blue when mixed with it: and having made this mixture, the effect answered my expectation; for though it produced some effervescence, it neither rendered the mixture blue, nor even its effervescing surface, though covered with froth; but both remained green, while secluded from the contact of atmospheric air, by being inclosed in a vessel well stopped; and I found it practicable in this way to neutralize the alkali completely, without rendering the indigo unfit to produce a fast

blue colour, or a green, when applied to yellows, if applied quickly; but when the topical blue, thus neutralized, had been kept some time, the indigo, being deprived of the alkali which had held it in solution, gradually subsided in a great degree, and became unfit to be applied topically. There is, however, I think, an intermediate degree to which the alkali may be neutralized, without precipitating the indigo, in any considerable quantity, at least for several weeks, and which will be sufficient to prevent the alkali from exercising any action injurious to the yellow colours upon which the blue may be laid.

The fluoric acid employed in this way answered as well as the muriatic; and I now find this to be true of the sulphuric and some other acids; there being no danger, as from some former inaccurate experiments I had once supposed, of a revival of the indigo, by mixing either of them with the topical blue, the attraction of the basis of indigo (in this preparation) for oxygene not being sufficient to decompose any of these acids, so far as I know. Carbonic acid is always present in the topical blue without being decomposed; and no injury is produced by other acids when mixed with it, so long as, by not being decomposed, they are incapable of reviving the indigo. I have ascertained also that the oxygenated muriatic acid will not revive it; a fact which I once thought favourable to the opinion of Scheele and Davy, that it contains no oxygene; but the other facts just stated, show that nothing decisive in that respect can be inferred from it.

It is to be observed that all the preceding means of rendering indigo soluble, by abstracting a part of its oxygene, serve only to bring it back to the state in which it existed while dissolved, and retaining its green colour in the fermenting process, before its minutest

particles had been collected together, in a concrete blue form, by agitation; and I have already mentioned, at p. 126, my persuasion, that the colouring matter of the indigo plant, in this fluid state, is not only fit for dyeing, but that the blue colour dyed with it, would, like that of the isatis, or woad, prove more permanent than that given by the indigo, after it has been made to assume a concrete form; because its basis, even by the least hurtful ways of dissolving it, will, I think, necessarily be in some degree weakened, as all other vegetable colours are found to be, by the action of such powerful agents as are requisite for that purpose; and I think it probable, that the very durable blues which are given by particular people in some parts of Africa, owe their superiority to this method of dyeing.

According to Mr. Clarkson, "it is well known, at least in the manufacturing towns, that the African dyes are superior to those of any other part of the globe." "The blue (continues he) is so much more beautiful and permanent than that which is extracted from the same plant in other parts, that many have been led to doubt whether the African cloths brought into this country were dyed with indigo or not. They apprehended that the colours in these, which became more beautiful upon washing, must have proceeded from another weed, or have been an extraction from some of the woods which are celebrated for dyeing there. The matter, however, has been clearly ascertained: a gentleman procured two or three of the balls, which had been just prepared by the Africans for use: he brought them home, and upon examination found them to be the leaves of indigo rolled up in a very simple state."

Sulphate of Indigo.

The powerful action of sulphuric acid upon indigo, and the very bright lively blue colour thereby produced, had been observed by chemists long ago, but no person seems to have applied this colour upon cloth as a dye, until about the year 1740, when it was done by Counsellor Barth, at Grossenhayn, in Saxony. In addition to the indigo and sulphuric acid, he employed crude antimony and lapis caliminaris, (and as some say, alum), mixing them with the oil of vitriol first, and adding the indigo afterwards: but these additions being found useless, were after some time discontinued.

When a bit of pure flora, or blue Guatamala indigo, is dropped into concentrated colourless oil of vitriol, in a flint glass phial, radiations of a bright greenish yellow may be seen almost immediately projecting from the indigo, and resulting from a solution begun upon its surface; and if the phial be left *unagitated*, these radiations soon become green, and afterwards blue, without any motion or change in their direction. This sudden conversion of the blue colour of the indigo to a greenish yellow, seemed to indicate an abstraction of oxygene, as its cause; but it was difficult to conceive how such an abstraction could result from the application of an acid, already completely saturated with oxygene. I recollected, however, that Berthollet had mentioned, as one of the effects caused by the action of sulphuric acid upon indigo, that, of its determining (as it does with sugar) the production of a little water, in consequence of the intimate combination which it effects between certain portions of the oxygene and hydrogene, which are among the constituent parts of indigo; a combination by which he accounts for the great heat, resulting from a mixture of powdered indigo with sulphuric acid,

and the *non* production of *sulphureous* acid thereby. This fact, of the production of water by a combination of a part of the oxygene of the indigo, with a part of its hydrogene, enables us to understand how the indigo may, and, indeed, must be deprived of a portion of oxygene, sufficient to change its colour, suddenly, to a greenish yellow; and this change being effected, the progress afterwards, to green and blue, accords with the series of changes observed in the topical blue of the calico printers, after its application; and indicates a restitution of the oxygene, taken from the indigo by the formation of water. To ascertain with certainty whence this restitution was made, or rather whether any part of it was derived from the atmosphere, I placed a small piece of the Guatamala indigo in a phial, and filling it completely with colourless oil of vitriol, I closed it immediately with its ground glass stopper, which came in contact with the acid and indigo, (the latter from its levity rising to the top) so as to leave no space for air. I then placed the phial at the window, and keeping it motionless, saw, by transmitted light, streaks of greenish yellow radiating downward from the indigo, and gradually changing and passing through all the intermediate shades of green, to a full sky blue; and as nothing could have been gained from the atmosphere during these changes, it was manifest that they must have been produced by something contained in the sulphuric acid; and as the latter does not appear in this operation to suffer any decomposition, nor the indigo to be capable of effecting any, I conclude, that when this last has been rendered soluble, by the *deoxygenation* resulting from a production of water, it enters into a triple combination with the oxygene and sulphur composing the acid, and thereby regains its blue colour, with additional brightness; either from its union with an increased proportion of oxygene, or from

some effect resulting from the sulphur, which had not been combined with it originally. But though the colour is rendered much more beautiful by this *triple* combination, it is accompanied with a great diminution of its former stability, and differs *essentially* from the solutions of indigo made by lime and alkalies, assisted by the deoxygenating agents lately mentioned; for when indigo is revived or recovered after the latter mode of solution, it is found to possess all the properties which belonged to it before it had undergone any solution, including its original indissolubility, (except by the agents already mentioned.) But after being dissolved by sulphuric acid, it can never be revived with its original and peculiar properties. It may, indeed, be readily precipitated by alkalies, but excepting a blue colour, the precipitate will differ from indigo in every respect. It will no longer retain the power of emitting its characteristic *purple smoke*, when ignited; and it may be readily dissolved, by all the acids, and alkalies, as well as by other agents which previously had no dissolving power over it; and, though most of these solutions are blue, their colour has but little permanency, especially those made with pure alkalies, whether fixed or volatile, as they soon spontaneously become green, and finally colourless.

When the basis of indigo, after being sufficiently deoxygenated, is dissolved by lime or alkalies, it forms no permanent combination with either, and may afterwards be separated and recovered from them without having suffered any perceptible injury or change. But the effect is very different after this basis has been dissolved by any of the acids; probably it suffers least injury from the sulphuric, though with this, indigo can hardly be said to produce a fast colour, even on wool, since, as Haussman observes, it is easily extracted by

soap in boiling water, and changed by alkalies to an olive colour, more or less yellow, according as the alkali is more or less caustic; and since the adhesion of this blue to linen and cotton is so feeble, that cold running water will gradually carry it off.

Bergman, (whose labours have thrown much light on the subject of indigo) ascribes the want of greater permanency in the Saxon blue, to the use of sulphuric acid, not sufficiently concentrated. He used an acid whose specific gravity, compared to that of water, was as 1900 to 1000, and employed eight pounds of this acid, to dissolve one pound of indigo. I believe, however, that he was misled on this subject, and that Pœrner is much nearer the truth, when he says, that the best proportion for dissolving indigo, is only four times its weight of good pure oil of vitriol; and that where more is used, the blue is less permanent. I am even inclined to think that the blue will prove more durable, if this last quantity of acid be diluted, with an equal portion of hot water, as soon as the indigo is put to it, and the mixture left in a warm situation 48 instead of 24 hours, for the indigo to dissolve; because, by a slower, and more moderate action, I think the basis of the indigo will be less weakened; at least I have frequently dissolved indigo in this way, and the colour has appeared to be more durable, than when it was dissolved by an undiluted acid.* The indigo being dissolved, Mr. Pœrner adds as many ounces of dried potash, as there were of indigo in the solution, which produces an effervescence; and after twenty-four hours, he adds eight pounds and a half of water, for each pound of oil of vitriol employed, and puts the whole into a glass

* If the indigo be *finely powdered*, it will be thereby rendered soluble, with a smaller proportion of the acid, and even that proportion may be more diluted.

vessel for use.* Instead of potash, I have used clean chalk, and this even in such quantities, as to saturate the vitriolic acid. The indigo was then precipitated with the chalk, and being collected in a solid mass, it was still capable of dyeing a blue on wool, though it took much more slowly than in the ordinary way of dyeing Saxon blue; in which the colour applies itself so rapidly to wool or wollen cloth, as to render it difficult to prevent its taking unequally, a defect which might probably be obviated by a small portion of chalk. It is to prevent this inequality, that M. d'Ambourney advises, where deep Saxon blues are wanted, to pass the cloth at different times through vessels containing only what might suffice for weak colours, in order that the blue may, by these partial applications, be made to take with more evenness. Silk, dyed along with wool, takes a much weaker colour, (I mean with the addition of chalk), because it has less affinity with the indigo than wool has. This preparation of indigo, however, would not give a deep blue, because being united with so large a portion of white sulphate of lime, the blue colouring particles could not be sufficiently condensed for that purpose. Pœrner conceives the Saxon blue to be rendered more durable by previously preparing the cloth with alum, and sulphate of lime.

The solution of indigo by sulphuric acid, is usually called by dyers chemical blue. It ought, however, according to the new nomenclature, to be termed sulphate of indigo; a name by which I shall continue to distin-

* Pœrner says, and I think truly, that by this addition of potash, a more agreeable blue is produced, and that it penetrates farther into the cloth. He mentions as an instance of the abundance of colouring matter afforded by indigo, his having dyed five pieces of cloth, each weighing one pound, of different shades of Saxon blue, all with a single half ounce of indigo.

guish it.* When applied to wool, the blue colour is much more permanent than it is in a fluid state; for though a little manganese, added to the sulphate of indigo, instantly destroys its colour,† wool, which had been previously dyed blue with some of the same preparation, was not discoloured by the action of manganese, dissolved in sulphuric acid.

I do not know that a black was ever produced by the sulphate of indigo, or by any other preparation of that drug alone. Mr. John Wilson, who greatly contributed to improve the art of dyeing at Manchester, has asserted, that though a redundance of colouring matter will increase the force and body of a colour, yet that no repeated dyeings of blue will become black. I have, however, now before me, two pieces of cloth, one of which is the deepest and purest black perhaps ever seen, and it was dyed by me, very lately, from sulphate of indigo, employed alone, though in an unusual quantity; the other is

* Pœrner describes a sulphate of indigo, which he prepared in a dry solid form, and reserved as a *secret:* he represents it as being more commodious, and advantageous for dyeing, than the common sulphuric solution of indigo. Berthollet conjectures (tom. ii. p. 97) that this may have been the precipitate which I had recommended, of sulphate of indigo, by an addition of carbonate of lime. It doubtless must have been a *precipitate* by this or other means.

† The *destructive* action which manganese exerts upon the colour of indigo, when it (i. e. the manganese) is mixed with sulphuric acid, though weaker, resembles that of muriatic acid, after it has been mixed with manganese; and to my conception, affords a strong presumption, that in both mixtures, the destroying power depends upon a co-operation of something *gained* from the manganese; which is, however, contrary to the notion of Scheele and Davy, that muriatic acid, by its admixture with manganese, and conversion to oxymuriatic acid, *gains nothing*, but is merely deprived of the hydrogene previously combined with it; and that this deprivation constitutes the whole difference between the muriatic and oxymuriatic acids. Manganese added to the topical blue, soon revives the indigo, but does not injure its colour.

a fine Saxon blue, which was cut off from the first, before it had taken up so much of the blue colour, as to become black. I lately found also, in making the topical blue, that a small piece of cotton, which I had thrown into the mixture, and which, being forgotten, had remained there forty-eight hours, was, when taken out, of a *full black*, so permanently fixed, that neither lemon juice nor alkalies seemed capable of impairing it. I could not, in one or two trials afterwards, succeed in producing a similar black on linen or cotton; and it must be remarked, that when I produced this, it was in a mixture to which I had at first put a little manganese, to see whether it would promote the dissolution of indigo; and finding it did not, I had afterwards added more than the usual proportion of orpiment; one or both of which additions, may have contributed to the black in question.*

* That Saxon blue, or the colour of indigo, in combination with sulphuric acid, depends upon the union of a certain proportion of oxygene, as in all other preparations of this drug, may be proved, by adding to the sulphate of indigo, a little muriate of tin, which by its ordinary deoxidating influence soon changes the blue, first to green, and then to a pure bright yellow. If this yellow mixture be applied to linen or calico, it will dry without losing its yellow colour, the affinities of the oxide of tin, or of the muriatic acid, or of both, counterbalancing that of the indigo for oxygene. But if the linen or calico be moistened with a weak solution of carbonate of soda, or potash, to neutralize the acid, the yellow will *return* through all the shades of green, to the former Saxon blue. Muriatic acid *without tin*, produces no change in the colour of sulphate of indigo, because it has alone no deoxygenating power. Analogous to the preceding fact, (now first mentioned) is that published by Vauquelin, of the deoxygenating influence of hydro-sulphurated water, which when mixed in a close stopped phial with sulphate of indigo, soon becomes green, and in a few days yellow; but if the phial be afterwards unstopped, the sulphate of indigo gradually returns through the different shades of green to its former blue colour, as fast as the separation of sulphuretted hydrogene permits the indigo to recover its oxy-

The sulphuric acid, or oil of vitriol, as commonly prepared, contains a small portion of the nitric, which, however small, necessarily does some harm in forming the sulphate of indigo. M. Chaptal observes, that he has seen the colour fail, and the stuffs intended to have been dyed spoiled by this fault in the sulphuric acid employed for that purpose, which ought, therefore, to be guarded against as much as possible.

The indigo of all others most preferred for Saxon blues, is the flora of Guatamala, which indeed is seldom employed for any other species of blue.

The other kinds, when mixed with oil of vitriol, effervesce sometimes very strongly, in consequence of the extrication of fixed air; the presence of which may easily be accounted for, by recollecting that lime is commonly employed to accelerate the separation and precipitation of the minute particles of indigo, while in the vessels called beaters, and that in doing this, it subsides with the indigo, after having absorbed carbonic acid, which in this way is again set free by the oil of vitriol. Here it will be proper that I should offer some conjectures on the cause of the different colours of indigo: and as a foundation for these, I must remark, that the flora, or blue indigo of Guatamala, is much lighter than the violet, and that this last is lighter than the copper-coloured. From the lightness of this *blue* indigo, and from its not effervescing with acids, when dissolved by oil of vitriol, there is the strongest reason to conclude that no lime is employed to accelerate the separation and precipitation of its colouring matter in the beaters; since, if there had been any, it would have increased the specific

gene. An undissolved hydro-sulphuret will act more efficaciously in this way, so as to render the sulphate of indigo almost colourless; after which, if it be applied to calico, the latter will first become yellow, next green, and then blue.

gravity of the indigo, and by absorbing carbonic acid, would necessarily have caused an effervesence, when dissolved in sulphuric acid; assuming, therefore, that no lime is employed to separate and precipitate the colouring matter, it would necessarily follow, that, to obtain such separation and precipitation, the agitation must have been continued longer than would otherwise have been necessary, and the unavoidable consequence would have been, the combination of a larger proportion of oxygene with the colouring particles so exposed to it, than that which takes place with those separated by lime: it will therefore follow, that indigo, obtained in this way, will contain a greater portion of oxygene than in the other; and it seems natural to conclude, that the blue colour is occasioned thereby. To ascertain, however, the justice of this conclusion as far as I was able, I took some of the lightest and bluest Guatamala indigo, and dissolved it by lime, potash, and orpiment, as usual; one effect of such solution, we know to be, the taking away from the indigo a considerable part, at least, of its oxygene; and I accordingly found, as I have done in all cases where indigo was dissolved for the topical blue, that the dissolution was accompanied with a bright shining copper-coloured pellicle upon the surface of the liquor, which of itself was of a greenish yellow underneath. The production of this pellicle may be easily explained by recollecting that the dissolved indigo, which has lost its oxygene, and become thereby of this greenish yellow, being at its surface in immediate contact with atmospheric air, regains a part of what it had lost, and by doing so, becomes copper-coloured; but swimming as it does upon a mixture disposed to attract oxygene, it cannot, in this state, retain so much thereof as the indigo itself formerly had, while it was of a blue colour; and, therefore, so long as the body of the liquor remains yellow or green, the pelli-

cle covering it, will be only copper-coloured, though consisting of a colouring matter which was formerly blue, and which would have become so again, if, being dissolved, it had been thinly applied to linen or cotton, and brought sufficiently into contact with the oxygene of the atmosphere. As therefore this blue indigo had apparently become copper-coloured, only by having less oxygene than before, is there not from this circumstance, an additional reason to conclude, that the copper-coloured indigo, separated and precipitated by lime, is made of that colour, only by its possessing a smaller proportion of oxygene than the blue indigo? and whilst this *blue* indigo is preferred for combination with sulphuric acid, as producing least effervescence, we should expect that the copper-coloured, as being the least oxygenated, would be most suitable for the indigo vats, and for the topical blue, because in these the dissolution is effected by taking away oxygene; and the less there is of it, the more easily will this be effected; and here the choice and practice of the dyers accord with my hypothesis, as they constantly employ the copper-coloured indigo for these last purposes.

Having already noticed all the *known* means or solvents by which indigo can be rendered useful in dyeing, I will only add a few observations concerning the effects of some other agents upon it.

If strong nitric acid be mixed with powdered indigo, its action upon the hydrogene of the latter will be so violent, as to produce actual combustion; and when diluted, its power, though moderated, will always prove destructive of all the useful properties of indigo, unless it be made so weak, as to manifest no sort of influence upon it. When it is of the strength of common or single aqua fortis, it dissipates a considerable portion of the component parts of the indigo, and converts the remain-

der into a rusty brown viscous bitter mass, which will burn and detonate, and which, according to Haussman, is soluble in alcohol, and also in water, when the proportion of the latter is very large. With a more diluted nitric acid, the indigo at first affords a bright yellow, but it soon changes to the rusty brown before mentioned; and the basis of indigo is then so completely decomposed, that the blue colour cannot be restored, by any of the various means which I have employed for that purpose.

The most concentrated muriatic acid, even with a boiling heat, has no action upon the pure colouring matter of indigo, though it dissolves some other parts of it; and this is true of the citric, tartaric, acetic, phosphoric, fluoric, and other acids.

A mixture of sulphuric, nitric, and muriatic acids, greatly diluted, will slowly dissolve powdered indigo, and change its colour to a very bright lively yellow, which appears to have considerable stability, though it could not be fixed on linen or cotton.

It is remarkable that though the strongest muriatic acid, even when boiling, has no influence upon the colouring matter of indigo, yet this, or even a much weaker acid, when it has been saturated by dissolving tin, will, if mixed with powdered indigo, in the common temperature of the atmosphere, speedily make it green, and afterwards yellow; holding a considerable portion of it suspended in the state of a yellow solution, whilst the residue subsides, as a powder of the same colour. In this case, the oxide of tin first produces a deoxygenation of the basis of indigo, and thereby renders it soluble by the muriatic acid, to which it was before inaccessible. But being so dissolved, this basis either undergoes a decomposition, or enters into a new combination with the oxide of tin, or the muriatic acid, or both, of a nature so inti-

mate, that no means which I have been able to employ, to remove or neutralize the acid, have enabled the indigo to regain its former portion of oxygene, or return to its former blue colour; as the sulphate of indigo will do by such means, when it has been made yellow by muriate of tin.

The insolubility which the basis of indigo acquires by combining with oxygene, may, as Berthollet observes, be compared to that of certain metallic oxides, which at a maximum of oxidation, cannot be dissolved by acids, but are made soluble by the application of means suited to produce an abstraction of oxygene. And here I may terminate my explanation of the extraordinary and highly interesting chemical properties of indigo, believing that it will suffice to enable my readers to understand, both the reason and effects of the several methods and means employed to fix its colour, by dyeing and calico printing.

It now only remains for me to mention some facts respecting the history of indigo, which have been purposely kept back, because I believed they would be read with more interest, and be better understood when the properties of this drug had been previously made known.

Mr. J. N. Bischoff, in a work which manifests great reading on the subject of dyeing, ("Versuche einer geschichte der Färberkunst, 1780,") appears to think, that the indigo with which we are acquainted, was unknown to the Greeks and Romans; that the *indicum* of Pliny was not a dyeing drug, but a paint very different from our indigo; and that the charter or contract which passed in 1194, between the cities of Bologna and Ferrara, respecting certain duties to be paid at the former city, upon the Grana de Brasile, (or Kermes), and upon indigo, alluded to the indicum of Pliny, and not to the substance now called indigo. It may, however, be de-

monstrated from the known properties of our indigo, and those which Pliny has distinctly mentioned as belonging to his *indicum*, that the former is an exact resemblance of the latter. After describing the preparation of a very costly fine purple substance employed by painters, (and obtained by skimming the vessels in which the Tyrian purple was dyed,) Pliny mentions, (lib. xxxv. c. 6.) the *indicum* as next in value and importance. "Ab hoc maxima autoritas *indico:* ex India venit," &c.—"cum teritur nigrum; at in diluendo misturam purpuræ cœruleique *mirabilem* reddit." After this mention of the country whence it was obtained, and of the admirable mixture of blue and purple colours which it exhibited by being diluted, he adds, that it had been frequently adulterated by pigeons' dung, and other fraudulent mixtures; and then, with great sagacity, he points out a trial by which the genuine drug might always, and *certainly*, *be distinguished from the spurious;* and this was by putting it upon *live coals;* where, says he, the true indicum will *burn with a flame of the most beautiful purple tint*. "Probatur carbone: reddit enim, quod *sincerum flammam excellentis purpuræ*." I have already, at p. 145, mentioned this purple flame, and the purple smoke accompanying it, as peculiarly distinguishing indigo. It was a *criterion* abundantly sufficient for Pliny's purpose, and the *only one*, which, in the then deplorable state of chemical science, could have been suggested by him. It is true that the Greeks and Romans, not knowing how to dissolve indigo, used it only in painting, but their ignorance did not alter its nature, or hinder it from being, as it must have been, the identical substance, with the uses and properties of which we are now so much better acquainted. It is true, also, that Pliny was mistaken, not in regard to the place whence it came, but in regard

to the way in which it was produced; he having supposed it to be a slime naturally collected in the scum of the sea, and adhering to certain reeds growing on its shores (" harundinum spumæ adhærescente limo"). And with this notion, he imagined that the peculiar odour of indigo, when burning, resembled the smell of the ocean, a circumstance which he says made some think it was gathered from the rocks (" dum fumat, odorem *maris* olet: ob id quidam e scopulis id colligi putant.") These notions, and the different names and circumstances which were applied to this substance, or mentioned as connected with it, by Dioscorides, Galen, Paulus Ægineta, and others, induced Caneparius, in his work " de Atramentis, &c." (p. 193) to adopt what he supposed to have been the opinion of the former, that two different colouring matters from India were known to the ancients, one naturally adhering to *reeds*, &c. as described by Pliny, but now, as he supposed, wholly unknown to the moderns; and the other, an *artificial* substance similar to our indigo, and which he supposed to have been extracted from the isatis, or *woad*, by boiling it in dyeing vessels, and collecting and drying the scum, or skimmings, (as Pliny had mentioned to be done to obtain a pigment by the dyers of Tyrian purple.) This, he adds, is called in vulgar language, " *Endego*," and is brought by merchants from India to Alexandria, in Egypt, and to Syria, and thence imported to this city of *Venice*, now become (says he) the *emporium of the whole world.**

* " Consequitur ergo ut,"—" duo atramenti indici genere fuerent a Dioscoride constituta, (unum) eorum prodidit naturale quod sponte ab arundinibus in India paludibus, instar spumæ vi solis exiens humor concrescebat colore purpureo, *quo tamen prorsus caremus.* Alterum vero indici genus scriptum nobis reliquit esse arte factum; dum enim in cortinis, hæc sunt vasa infectorum in quibus

This work of Caneparius, was printed in 1619, at *Venice*, (where he lived, and where dyeing was then more practised, and better understood, than in any other part of Europe:) and I adduce his testimony chiefly to correct an error into which M. Berthollet appears to have fallen, when (at p. 22, of the first volume of his Elements, &c.) he asserts, that the *first indigo* made use of in Europe, was imported from the East Indies by the *Dutch.** The fact is, that for a considerable time before the first voyages of the Dutch, to the East Indies, were made, indigo, in considerable quantities, had been imported through Egypt and Syria, to Italy, *and employed in dyeing*. That this was one of the uses of that which Caneparius mentioned, as being imported through those countries from India, is evident from his next page (194), where after noticing the fact, of its having been formerly employed as a medicine, he adds, that in his own time, it was *used by the dyers and writers;* that the former were accustomed to dissolve it in vats, with a lye of wood ashes, and other wares, according to their own practices, concerning

tingunt pannos, ebullit *glastum isatisve* herba dicatur, et vulgo *guado*, tunc efflorescit, innatatque spumma purpurea, quam seduli artifices detrahunt, et siccant." This, he adds, is "quod vulgus appellat *endego*, corrupto vocabulo; hoc a mercatoribus defertur ex India, Alexandriam Ægypti, et in Assyriam, demum ex illis partibus in hanc *Venetiarum* Civitatem *universi mundi Emporium advehitur.*" That Caneparius was not accurately informed of the plant which afforded indigo, or of the method in which it was obtained, will surprise no one who is told that, according to Mr. Ray, botanists, even when he wrote in 1688, were not agreed on this subject, though the plant was suspected to be a leguminous shrub, belonging, or allied to the genus *Colutea.*

* "Il paraît meme que le premier, (indigo) qui ait été employé en Europe, nous a été apporté des Indes orientales par les Hollandais."

which, says he, it is not my office to give instruction.* Caneparius was a physician, and not likely to have been minutely informed in regard to these practices; and yet, in the same page, he describes very accurately, the method of preparing, for dyers' use, the *isatis*, from which he believed the indigo to have been extracted,† and from which indigo may indeed be obtained.

I find among my papers, a statement, which I made some years ago, on the authority of Sir Hans Sloane, (and taken, as I believe, from his Natural History of Jamaica, &c.) importing, that the annual consumption of indigo in Europe, about the year 1620, (soon after the time when Caneparius wrote) amounted to 350,000lbs.; and that this came principally by the way of Aleppo, where it was computed to cost 4*s.* and 6*d.* the pound. It is probable, therefore, that the Dutch had not then begun to import indigo, by the Cape of Good Hope; or at most, that they imported but very little of it. That it had previously, for a considerable number of years, been imported through or from Turkey, is evident from several facts, and among others, from Mr. Hackluyt's "Remembrances for Master S——," who, in 1582, was going to Turkey, and, among other things, was instructed "to know, if *anile*, that coloureth blue,

* "Usus igitur indici est hodierno tempore *tinctoribus*, et scriptoribus: *nam dissolvunt eum tinctores* in Caleariis cum lixivio, et aliis more suo, hæc tamen vos docere non est meum institutum."

† "Isatis est herba, quæ ante florem colligitur, et sub mola tunditur, et facto ex ipsa cumulo maceratur soli, mox in magnos globos redacta, et sub tecto locata aspergitur aqua, ut magis, potiusque, maceretur tunc edit magnum fetorem, et nigrescit, et sic præparatio isatis sive glasti dicatur idem est, perficitur ad tincturas," p. 194. The supposition of Caneparius, that indigo was obtained from the isatis, or woad-plant, seems to have been prevalent even in this country, so late as 1640, when Parkinson, who was then treating of indigo, called it "indico, or *Indian woade*."

be a *natural* commodity of those parts, and if it be composed of an herb?" See Voyages, ii. p. 161. Ed. 1599.

Bischoff has, however, furnished decisive evidence to prove that the use of indigo in Europe, as a dye, was anterior to the first voyage made by the Dutch to the East Indies. He tells us, (Versuche, &c.) that the appellation or distinction of woad dyers, among the Germans, may be found in a charter, dated so early as the year 1339; that with these, certain Flemish and Italian dyers, who had resorted to Germany, were afterwards incorporated under the name of ART, WOAD, and FINE Dyers: that they excited the jealousy and enmity of a more ancient corporation, the black dyers; and as indigo was employed by the former, the black dyers, influenced by this enmity, exerted themselves with so much success, in decrying this dyeing drug, that the Elector of Saxony, and Duke Ernst the Pious, issued severe prohibitions against the use of it; and that even in the Diet of the Empire, it was described as a pernicious eating devil, and corroding dye stuff, "*Fressende Teufels*," &c.; and for these prohibitions of the Elector of Saxony, he refers to the Codex Augusteus, part 1, p. 236, under the dates of 1521 and 1547; and in regard to the opprobrious appellations applied to indigo in the Diet of the empire, he refers to a work printed at Frankfort, in 1577; all which dates are much earlier than any of the voyages of the Dutch to the East Indies.

In what way indigo was first dissolved, or used for dyeing in Europe, I know not; but in the old collection of *recipes*, which I have mentioned in the introductory part of this volume, as translated from the Dutch, and printed in London, so early as 1605, I find one at p. 32, respecting the use of indigo, which is there called flora,

or "*floray*,"* and directed to be fermented by the *vat* process, with wood ashes, bran, and greening weed, (probably weld), and the appearances indicating the fit-

* In the act of the 23d year of Queen Elizabeth, cap. ix, indigo is designated by the names of "*ancle*, alias *blue inde*."—How long the vulgar Italian name of "*endigo*," mentioned by Caneparius, had prevailed in that part of Europe, I am not able to ascertain; but it appears to have been afterwards adopted and spelt with exactly the same letters, in the account of Canche's voyage to Madagascar, and by other French writers of that time; and our name of indigo has manifestly been thence derived.—The Spaniards and Portuguese, who had found the way to India, by two opposite courses, at a much earlier period, and there became acquainted with this production, adopted the Hindu name of anil, and aneileira; and these are the nations by whom indigo was first manufactured in America, viz. by the Portuguese in Brazil, and by the Spaniards in Mexico, where they each recognized the plant growing spontaneously. It seems extraordinary, therefore, that professor Thomas Martyn should have erred, as he has done, in his recent edition of Miller's Gardener's Dictionary, by representing "nil or anil" as "the American name" of indigo, and concluding, that the Portuguese had borrowed their name from the Americans, not from the people of India.—Though the French and English were later than the Spaniards and Portuguese, in encouraging the manufacture of indigo in America, they afterwards made considerable progress in it. The former exported from the island of St. Domingo only, in 1774, 2,350,000lbs. weight of this commodity; and nearly about the same time, in 1773, in the space of twelve months, 1,107,000 pounds weight of it, were exported from South Carolina. But in both places, the manufacture of this commodity has ceased, from new, though different circumstances. The deficiencies, however, which might have resulted from these changes, have been fully obviated by an increasing production of indigo in the East Indies. The importation and sale of this commodity, at the East India house, in 1792, amounted only to 581,827lbs. whilst the importation into Great Britain, from other parts of the world, amounted to 1,285,927lbs.; since which time the latter importation has gradually declined to less than a fourth of the former amount; whilst the importation from the East Indies, and sales at the India house in the year 1806, amounted to 4,811,700lbs.

ness of the fermenting liquor, to be applied to the stuffs to be dyed, are distinctly pointed out; especially that of its becoming *green.* How early this had been known, or how long this collection of recipes had existed in Dutch, or any other language, previous to the English impression in 1605, I cannot say; but there is, I believe, no reason to think that the Dutch had even then began to import indigo.

That this artificial production was first obtained from India, is proved by the testimony of Pliny, and other ancient writers, confirmed by a variety of circumstances; and particularly by its name, which is known, from numerous authorities, to have been *nil* in the *Hindu* language, from the earliest times, in which there is any authentic mention of it: and this name still continues to be given by the Hindoos, to all the plants whence indigo is obtained by them; not excepting the nerium tinctorium, from which Dr. Roxburgh believed that no indigo had ever been obtained until his discovery respecting it. The late Sir William Jones has however stated in the fourth volume of Asiatic Researches, that a Hindoo peasant, who brought this shrub to him, gave it the name of *nil*, which signifies blue in the language of that country. "A proof," adds he, "that its quality was known to them, as it probably was to their ancestors, from time immemorial."—When the Arabs and

and produced in sterling money 1,685,275*l.*; and the importation and sale at the India house, in the following year, amounted to 5,153,966lbs. and produced the sum of 1,863,091*l.* sterling.—I have no accurate account of the sales of East Indian indigo since 1807. They may probably have diminished a little within the last year or two, because the obstructions to the exportation, resulting from the peculiar circumstances of the existing war, have considerably reduced the price of this commodity; the importance of which, as a dyeing drug, greatly exceeds that of any other.

Egyptians afterwards obtained a knowledge of indigo, and of its use, (as they did of many other things), from India, they naturally adopted the name, with the substance itself; the Arabs calling it nil and nir, as Julius Scaliger long since mentioned, (in his book, on plants,) and the Egyptians giving it the name of nil, or neel. It is stated in the Memoirs of the Baron de Tott, (p. 278,) that the seeds of the indigofera tinctoria, with which the Egyptians dye their only garment (a linen shirt) are imported *annually* from Syria; Egypt being a *hot-house* which *exhausts* the plant, before the seeds can ripen. The Egyptians, therefore, were not likely to be the first discoverers of a manufacture, depending on a plant, which could not yield *prolific* seed in their own country.

Concerning the history of the isatis, or woad, I shall make but a very few observations. It was called by the former name among the Greeks, and particularly by Dioscorides; but it bore that of *glastum* among the Gauls and Germans, which, in their language, signified glass: hence Cæsar, in the 5th chapter of his 5th book, de Bello Gallico, says, "omnes vero se Brittani *vitro* inficiunt, quod cæruleum efficit colorem: atque hoc horribiliore sunt in pugnæ aspectu."—Pliny distinguishes it sometimes by the Greek, and at other times by the Gallic names; and in the first chapter of his 22d book, he mentions it as resembling the plantain, and as being called glastum by the Gauls; and though he does not repeat Cæsar's observation, that the Britons made their skins blue with it, in order to appear more terrible in battle, he says, that their wives and daughters painted their bodies with it, when they appeared *naked*, at the sacred festivals, so as to resemble Ethiopians. He had previously mentioned, in the 7th chapter of the 20th book, that this plant was employed to dye wool.

But though the Britons in Cæsar's time appear to have cultivated enough of the woad to dye their skins, the inhabitants of this island at a later period, obtained it from abroad, to dye their *garments;* and, indeed, they are said to have depended wholly on the French for it, until 1576. But in 1582, Hackluyt remarked, that "it was *then* brought to good perfection, (in this kingdom) to the great loss of the French, our old enemies." (See Voyages, &c. vol. ii. p. 161. ed. 1599.) I do not find that the woad plant has ever been observed to give a blue colour to the milk of cows, like the indigo, which, when eaten by them, not only renders their urine blue, but, according to Dr. Garden, of South Carolina, the cream of their milk also became "of a most beautiful blue colour." See Phil. Trans. vol. l. p. 296.

Gardenia Genipa.

The *Genipa* Americana of Linn. has recently been united to the genus named Gardenia, by the late John Ellis, Esq., in honour of Dr. Garden, formerly of South Carolina. Swartz, on whose authority this change was principally made, has strangely represented this, as being only a shrub, though I have frequently seen the tree growing 50 or 60 feet high, with a trunk five or six feet in circumference. Its fruit, (the only part connected with this subject,) is technically denominated a *berried drupe*, nearly of the size and shape of a lemon, a little pointed, and umbilicated at the end, and covered by a skin, which, whilst *unripe*, is of a light ash colour, with a slight appearance of green; immediately under the skin, is a white solid fleshy substance, moderately succulent, about one third of an inch in thickness, surrounding a soft pulpy matter, of an oval form, and about an inch in diameter, consisting of two cells, in

which many flattened roundish seeds are nestled in rows.

If this fruit or berry, whilst unripe, be sliced or broken, and exposed to atmospheric air, its colourless substance, or the clear juice expressed from it, almost immediately acquires a strong deep blue colour, and is universally employed by the savage tribes of Guiana and Brazil, to stain their skins with a variety of spots, lines, and figures, for the purpose of ornament at their feasts and dances, as well as to render themselves *terrible* to their enemies when going to war; as the isatis, or woad, was employed by the Britons in Cæsar's time. But the most singular circumstance attending this application is, that no repetition of washing with soap, nor any other application, so far as I could learn at the several times of my being in Guiana, appeared to have the smallest power to remove the blue stains so produced, until after some days, (generally nine or ten;) when the epidermis, or scarf skin, by perspiration, rubbing, &c. appears to wear away, and make room for another, which is untinged; and it is in this way *only*, as I believe, that the stains in question spontaneously and gradually disappear, after some days.*

Oviedo seems first to have mentioned this tree by the name of xagua; but he describes the colour produced by its unripe fruit, as being *black*, adding that the stain given by it to the skin, cannot be removed in less than ten or twelve days; and that it never can be effaced from the finger nails, until by their growth or

* Since my last return from Guiana, I find it stated by Hartsinck, ("Beschryving van Guiana," i. 49,) that the acrid milky juice of the fruit of the *carica papaya*, or papau tree, will remove the stains in question; which, if true, is a curious fact, and I regret not having been informed of it, whilst I had proper means to ascertain the truth *experimentally*.

elongation the stained parts can be removed. Francis Ximenes afterwards mentioned the tree by the name *xahuali*, which it bore in New Spain; he says, the stain is only to be removed from the skin after fifteen days, and never from the nails, except by their growth and separation, as explained by Oviedo. Marcgrave, (Brazil. p. 90,) described the tree under the names of janipaba, and janipapa, by which the Brazilians called it, and from which the more prevalent name of *genipa* was derived. He says, " immaturus fructus concisus, et cuti affricatus, tingit colore ex nigro sub cærulescenti, qui nullo modo ablui potest, sed post octo aut nona dies sponte evanescit."

Piso (at p. 138,) asserts, that the stain spontaneously disappears, not only from the *skin*, but from *paper* in about nine days, " tinctura enim illius corpori, vel *charta* illita circa nonam diem evanescit." An assertion which has been often repeated, and generally believed, though it never had any better foundation, than a presumption, that because it did not remain on the skin, it would not remain upon paper; and hence it was concluded, that dangerous frauds might be practised, by writing with this colour instead of ink. Coppier had, indeed, made this assertion some years before, ("Histoire et Voyages des Indes occidentales," printed at Lyons, 1645, p. 91.) And he pretended that the fact had been first discovered by himself, and that he had endeavoured to consign it to oblivion for the prevention of fraud. There was, however, no foundation for this pretension. I have now before me, both parchment and paper, on which I wrote with the juice of the unripe fruit of the tree under consideration, seven years ago, and it has not, as far as I can discover, suffered the smallest decay; and there is good reason to believe it would prove even more durable than the common writ-

ing ink, though it differs from it, by inclining much more to the dark blue colour. The *fable*, however, of the fugitive nature of this ink, and the dangerous purposes to which it might be applied, was so generally and firmly believed, by the inhabitants of Essequebo and Demerary, that I was induced to report it as credible in the volume, which, at an early age, I published respecting the Natural History of Guiana, in 1769.*

This tree, like the nerium tinctorium, asclepias tingens, &c. belongs to the *natural* order of *Contortæ*, and is known at Essequebo, Demerary, and Berbice, by the *Arrowauk* name of *launa*, and at Surinam by that of *tapouripa*, which undoubtedly was borrowed from some of the neighbouring tribes, probably the Carribees, with whom the first (English) settlers in that colony had more communication than with any other; though I cannot find this name in any vocabulary of the language of that people. Mad. Merian has mentioned this tree inaccurately, under the name of *tabrouba*, and has intended to represent a branch of it, at her

* Francis Ximenes mentions that tricks were sometimes practised with the juice of this fruit, by privately mixing it with rose water, and giving it to the ladies in New Spain; and Dutertre, in his Account of the French West India Islands, writing of this tree says, "il porte le *fard* des chambrieres nouvellement venues." He adds that the simple maid servants, who, in considerable numbers, about that time, came to the West Indies from France, were told upon their arrival, that unless they washed their hands and faces with the (colourless) juice of this fruit, their skins would become *black*, and that, believing this, they eagerly collected and applied the supposed means of preserving their complexions, and were astonished, soon after the application, to find their faces and hands covered with a hideous dark blue stain, which nothing could remove for nine or ten days. He indeed mentions his having married considerable numbers of them, before this stain had been removed, and repeats the fable respecting the supposed frauds which might be practised by using the juice of this fruit as a substitute for ink.

43d plate, but has *transposed* the explanation, or description, belonging to this plate, by joining it to her 48th plate, and connecting to the former that which relates to the latter; a blunder which no person seems to have before noticed.

When this volume was first published in 1794, I believed, and stated my belief, that the blue colour of the fruit in question, like that of indigo, resulted from a combination of oxygene, with a vegetable basis; and in fact that it was similar to indigo. And this belief was principally founded upon my having, when at Surinam, in 1770, applied the *colourless* juice of the fruit to pieces of linen and calico, and seen the parts to which it was applied speedily become blue, as happens with the indigo and woad plants; and upon my having found that the colour so produced was not discharged by repeated washings with soap, nor considerably injured by exposure to the sun and air for several days: my experiments at that time were, however, but few in number, and made under the disadvantage of being then but little acquainted with the subject of dyeing: wishing, therefore, for greater certainty respecting the nature and properties of this colouring matter, I determined, when I visited Guiana a third time, in 1805, if possible, fully to investigate the subject. And accordingly having observed, soon after my arrival in Demerary, a young gardenia genipa tree growing on the plantation Reinsteen, then belonging to Messrs. Brummell and Addison, which tree, though probably bearing for the first time, exhibited two or three dozens of the berries or fruit, each about the size of a nutmeg. I informed Mr. Brummell of my wish to make experiments with them at the proper time, and with his usual kindness, he immediately ordered that they should be all carefully preserved for my use. In a few weeks after, I observed the tree to have shed all its leaves, (as happens to trees of

this species at certain seasons,) and that it afforded the uncommon spectacle of a *leafless tree bearing fruit.*

About this time, circumstances connected with the state of my health, determined me to return immediately to Europe, by the way of Barbadoes; and having no leisure to make even a single experiment, the fruit of this tree, which had then almost attained its full growth, were all gathered, and embarked with my baggage. But finding soon after my arrival at Barbadoes, that they were becoming soft, and in danger of spoiling, before I could conveniently make the experiments which I intended, I caused them to be sliced and dried in the sun; presuming that they might afterwards be preserved several years, like the indigo plant, in a state fit for my experiments. But while this was doing, the sudden transition of the whole inner colourless substance of the sliced fruit, to a full dark blue, without any intermediate yellow or green tint, engaged my attention, as indicating an *important difference* between this, and the basis of indigo; for it was hardly credible that the affinity for oxygene should be so much greater in the former than in the latter, as to enable it *at once* to become blue, without even the momentary appearance of an intervening green.

By the part which I took in slicing this fruit, my fingers were deeply stained; and as this stain might well seem *indecorous* to the gentlemen and ladies, with whose hospitalities I was daily honoured, I spared no pains to remove it, by repeated washings with soap, alkalies, &c. and by frequent applications of lemon, and lime juice, but without producing any sensible diminution of this troublesome dark blue colour, until it disappeared in the usual way, by an apparent abrasion of the cuticle.

I did not neglect, when in Barbadoes, to apply some of the juice of the sliced fruit, by which my fingers were stained, to pieces of calico, impregnated with alumine,

and the oxide of iron, as well as to some which had no impregnation, and I afterwards found that neither of these bases had any affinity for the colouring matter under consideration, it being in no respect changed thereby. The calico without any basis, had acquired a very dark blue tinge, which was not altered by washing with soap, nor by exposure to sun and air for some days; though in this respect it seemed to be less permanent, than I had believed it to be, from my former experiments in Surinam.

Since my return to London, I have made such trials as to me appeared suitable, with the sliced and dried fruit of the gardenia genipa, which, though more than seven years have elapsed, still retains a dark blue colour; but this manifestly depends on principles very different from those of indigo. For it is soluble both in potash and soda *alone;* and when lime and orpiment were added to these, *no* change of colour ensued (from blue to green,) indicating a susceptibility of deoxidation. Sulphuric acid seemed to brighten the blue colour as it does that of indigo. But (unlike sulphate of indigo,) *this mixture* appeared to have no affinity for vegetable substances, and so little for the animal, that cloth by long boiling in the *blue* liquor, would only receive a slight drab colour. Nor does the juice of the fruit seem capable of permanently staining the fingers, after it has already become blue. The addition, whatever it be, which occasions the blue, if made *before* it touches the skin, rendering it incapable *afterwards* of attaching itself either to animal or vegetable substances. Nitric acid changes the blue to yellow, as it does that of indigo.

Several writers have asserted, that the fruit of the gardenia genipa when *ripe*, becomes yellow, and loses its disposition to assume a blue colour. Whether this colourable property was in any degree affected, by my having kept the fruit in question, until it was approach-

ing towards rottenness, (which might produce effects like those of ripeness), I know not; but as its blue colour evidently results from causes, differing greatly from those which produce the colour of indigo, it seems very desirable to ascertain their nature; though I think this can only be done by trials upon the *unripe and recently gathered* berries, which, while their juice remains colourless, might be placed, some *in vacuo*, others in the several gases separately, and exposed to the sun's rays, as well as kept in *obscurity*, to discover which of these situations and agents contributed most, either to hasten or retard the production of the blue under consideration.

Brown, in his History of Jamaica, p. 143, observes, that "the pulp of the berries of the Randia aculeata, Linn. (called in that island the indigo berry, and which grows plentifully on the smaller branches of the plant,) is very thick, and stains paper or linen of a fine fixed blue colour. I have tried it (continues he) on many occasions, and have always observed it to stand, though washed with either soap or acids; but it does not communicate so fine a colour with heat. It would prove (he adds) an excellent fixed blue in all manner of paints and prints, if it could be obtained in any quantity; but the berry is not very succulent, and the people as yet are not very industrious in these parts."

This plant, like the genipa, has recently been added to the genus *gardenia*, (under the name of gardenia aculeata,) and it is remarkable that their generic characters being similar, their fruit also should yield *blue* colouring matters, which, as far as I know, seem to resemble each other. The indigo berry, in like manner, belongs to the *natural* order of *contortæ*, which, more than any other, contains plants yielding the *blue* colour.

Mr. Martin Lister (in the VIth Vol. of the Philosophical Transactions, page 2132,) mentions that "the

seed husks of glastum sylvestre, old gathered and dry, being diluted with water, stain a blue, which, upon the affusion of lye, strikes a green; which green or blue, being touched with the oil of vitriol, dyes a purple; and all these colours (says he) stand." Some of the mushrooms also become blue, when exposed to atmospheric air. The same effect, according to Sennebier, happens to the milky juice of the tithymalus euphorbia, Linn.

It is mentioned somewhere in the Swedish Memoirs, by Cronsted, that the stalks of the polygonum fagopyrum, Linn. by fermentation in water, afford a blue which did not change either by acids or alkalies.

Green Indigo.

About the year 1790, Mr. Alderman Prinsep, who had then lately returned from *India*, gave me a specimen of indigo obtained *there*, as he informed me, from a tree, (which I then suspected to be the panitsjica-maram, of the hortus malabaricus, though I now suppose it must have been produced from the nerium tinctorium, lately mentioned;) and he, at the same time, gave me a very small piece of a hard green substance, likewise produced in the East Indies, and which he called *green* indigo.

Upon seeing it, I flattered myself with a hope of its proving to be what the late Mons. de Poivre had mentioned in a little work, published under the title of "Voyages d'un Philosophe," &c. as obtained by the inhabitants of Cochinchina from a plant called *tsai*, which, when macerated and fermented like indigo, yields a *green* fecula, capable of dyeing a fine, as well as a lasting emerald, or green colour.* The quantity of this

*Loureiro mentions, (tom. i. p. 25, of the original Lisbon edition,) the justicia tinctoria, as growing wild in Cochinchina, adding, "folia viridi colore staturata, eodem telas pulchre imbuunt." Whether the plant, whose leaves alone are here represented as

green substance so put into my hands, was much too small even for a single decisive experiment. I however divided it into three parts. One of these I put into boiling water, which appeared to have no action upon it; but it was afterwards dissolved by a little oil of vitriol, like common indigo, producing, however, a green, instead of a blue colour. A second of these parts I dissolved with a little caustic alkali and orpiment, in order to see whether, excepting the difference of colour, it would possess properties similar to those of indigo, when dissolved by the same means, and like the latter be able to produce a fixed colour on linen or cotton by topical application. This, however, it did not seem to be capable of doing: the remaining part I put into a little spirit of wine, which dissolved a portion of it, though very slowly; a circumstance in which it differs materially from indigo, and seems in some degree to resemble that green-coloured fecula which some plants afford, and particularly the cruciform, when fermented like the indigo plant in warm weather. I confess, however, that these experiments were made on such very small quantities of the substance under consideration, that very little dependence ought to be placed upon them. But this is certain, that if a simple or homogeneous *green* colouring matter exists, and can be discovered, with properties in other respects similar to those of indigo, it will be a most important addition to the Materia Tinctoria.

Barasat Verte.

In the year 1793, Messrs. John and Francis Baring, and Co., received from R. C. Birch, Esq. of Calcutta, parcels of two new drugs, intended for dyeing; samples of which were put into my hands, with a request that I

capable of producing a *green dye*, has any relation to the *tsai* of M. de Poivre, I know not.

would make suitable trials of their merits; and with a paper containing some explanations which had accompanied them from India. One of these (and the only one which I shall notice at this time) was called Barasat Verte, and was formed into dry hard cakes, resembling in size and shape those of the indigo sent from Bengal; but of a dark dull green colour. It was stated to be a simple substance, and to have been prepared with water and fire only, "from an *indigoferous* plant, an ever-green, with leaves somewhat resembling those of the laurel, bearing large clusters of small yellow flowers, and producing seed in large pods, pointed at the end, and it was added, that the *seed did* "*not vegetate in Bengal.*" It was also represented as giving a durable light green colour, without any mordant or basis, to silk and wool; and to be incapable of dyeing dark green without the aid or addition of some blue colouring matter. To bring this green indigo into a state fit for use, it was directed to be finely levigated with sand, and then boiling hot water was to be poured upon the powder in a suitable vessel; and being left to settle, the water "tinged with a dirty brown colour was to be poured off;" and these washings were to be repeated until the water came from the powder colourless; and then to the remaining powder an equal quantity of fixed vegetable alkali, obtained by calcining salt-petre upon burning charcoal, was directed to be added, with a proportionate quantity of water, and the mixture made to boil for two or three hours; after which, it was to be left "to digest for two days at least." In this preparation, diluted with boiling water, the silk or woollen stuff was directed to be dipped for the space of half an hour, and then washed with soap in water; a longer dipping was represented as giving no greater body or depth of colour.

After what has been just mentioned on the subject of *green* indigo, it will naturally be concluded, that my curiosity must have been greatly excited by that now under consideration; and indeed I lost not a single minute in making such a trial of it, as would decisively ascertain whether it really possessed the properties of indigo, with only the difference of a green instead of a blue colour. This was by powdering and boiling it in water with a suitable portion of lime, potash, and red orpiment, as is practised in making the printer's blue for penciling, (see page 154, &c.); and in doing this, I soon perceived, with great satisfaction, that the mixture exhibited exactly the same smell, and the same appearances, as those which arise in making the printer's blue; the surface of the liquor was covered with a fine shining copper-coloured scum, and beneath this, when separated, the liquor itself exhibited a lively green. Being impatient to see how far its effects were similar to those of indigo dissolved in this way, I applied some of the green liquor as expeditiously as possible, by the pencil, to a bit of calico, and soon perceived that it consisted of two very dissimilar colouring matters; one, which proved to be true indigo, was immediately revived by an absorption of oxygene, (as happens to the printer's blue when so applied,) whilst another part of the liquor spread itself farther, and retained a kind of olive green colour, which the air did not change.

The calico, after being dried, was washed with soap, and that part of the liquor which had spread farthest, and retained the olive green colour, was soon wholly washed out, leaving behind the pure indigo, adhering to the spots and strokes where it had been applied. Having thus convinced myself that this substance contained a portion of true indigo, I powdered an ounce of it, and mixed the powder with six times its weight of sulphuric acid, as in

making the sulphate of indigo for Saxon blue: in about twenty-four hours the powder appeared to be nearly all dissolved, and the solution was of a blue colour, with a greenish tinge: and by putting a little of it into warm water, and dyeing a small piece of flannel therein, a full Saxon blue was soon produced; though the colour had a greenish cast, occasioned manifestly by the same olive-coloured matter which I have just mentioned as having showed itself upon the calico.*

I afterwards tried the method recommended by the author of this discovery, of separating the yellowish brown colouring matter from the powdered green indigo, by repeated ablutions with hot water, and then employing a pure caustic vegetable alkali to dissolve the residuum. In this way I obtained a solution which, upon wool, dyed a light olive or apple green; I found, however, as I had foreseen, that none of the true indigo had been dissolved, either by these last trials, or those made in Bengal, it being impossible, as I have formerly explained, to dissolve indigo by caustic alkali alone; and indeed the discoverer of this preparation, in the account which he transmitted from Bengal, candidly acknowledges that he had never been able to dissolve the supposed green indigo "entirely, a considerable quantity having always remained precipitated at the bottom of the vessel." And this insoluble residuum, (which appears to have been lost, or at best to have remained wholly useless in all the experiments made in Bengal), I found by further trials to be true indigo. For by separating the solution made by

* A small bit of the Barasat Verte being ignited, it burnt with a brisk red flame, emitting fumes, of which a considerable part exhibited the fine purple tint peculiar to those of indigo. It left a residuum, equal to about half its bulk, of a dark chocolate colour, of which carbon seemed to constitute a considerable part, but this I did not particularly examine.

caustic vegetable alkali from the residuum, then pouring upon the latter farther portions of caustic alkali in hot water, until the lixivium came away colourless; and afterwards submitting what remained to the action of muriatic acid, to dissolve any heterogeneous matters which the alkaline menstruum had left behind, I at length obtained a considerable quantity of indigo, of a middling quality; part of which, being dissolved by sulphuric acid, dyed wool of a good Saxon blue colour, without any of the greenish tinge which had attended my first trials; and another part being dissolved by potash, lime, and red orpiment, as for the printer's topical blue, produced the usual effects of indigo in this way. Having applied the acetite of alumine topically to a piece of cotton, as is practised in calico printing, and dyed one part of it in the yellowish brown coloured liquor, which had been obtained by pouring hot water on the supposed green indigo in powder, and another part in the olive green liquor, obtained from the same powder by caustic vegetable alkali, I found that, though each imbibed a different colour, neither was fixed upon the figures which had been printed with the aluminous basis, or on the parts to which no mordant or basis had been applied, and that the colours were removed by washing with equal facility from every part: a certain proof that the yellowish brown and olive green colouring matters were not of the adjective kind, (having no affinity with the aluminous basis,) and that they are not likely to be of any use in dyeing; for though they should prove lasting upon woollens, there are many other and much cheaper means already in use for giving colours of this kind to wool. It seems evident, therefore, that the true nature of the supposed green indigo was but very little known to the discoverer thereof; and that its useless heterogeneous parts were the only ones which

produced the colours dyed in Bengal, and which induced him to send it to Europe as a dyeing drug.

Whether the supposed green indigo owes its production to an insufficient combination of oxygene; or, in other words, whether the matters which dyed the yellowish brown, and the olive green colours, before mentioned, are similar to that which forms the basis of true indigo, and capable of being converted thereto by a longer fermentation, agitation, &c.; or whether they are of a nature essentially different from the basis of indigo, though naturally combined with it in the particular plant whence the substance under consideration is extracted, are important questions which I am unable to answer. I have indeed mixed the supposed green indigo, in powder, with water, and kept the mixture for several days at a degree of warmth suited to promote a fermentation, but without being able in this way to render its colour blue, or increase the proportion of true indigo which it had before contained: but perhaps I might have been more successful with a greater quantity, or a larger fermentable mass, than what I was able to employ in this way.

I have had reason to conclude, that the supposed green indigo, either from a redundance of colouring matter in the plant from which it was extracted, or from some other cause, may be obtained at much less expense than the true indigo; and if this be the case, it must doubtless prove a very important discovery, if the yellowish brown and olive green matters are capable of being changed to indigo, by a farther combination of oxygene: and even if this should not be the case, perhaps the plant may deserve attention, on account of the portion of true indigo which it unquestionably affords; and which, by an alteration in the process, might doubtless be precipitated and collected, free from the other matters before mentioned, which, at best, can only be considered as a troublesome

incumbrance, without any such benefit as Mr. Birch appears to have expected from them.

The preceding account of the *Barasat Verte*, was published by me in 1794, excepting the *names*, which I did not consider myself as at liberty to mention. I had not then been informed that when my attention to this subject was requested by Messrs. Baring, the nearest relation of Mr. Birch in this country, had also engaged Dr. Higgins to employ his chemical science and means upon the same matter; and, consequently, the report which I made, and which was transmitted by Messrs. Baring to Calcutta, was founded solely upon the results of my experiments. I discovered afterwards, however, by some letters from Mr. Birch, (of which extracts were communicated to me,) that the report of Dr. Higgins, in regard to the merits and value of the Barasat Verte, had been much more favourable than mine; he having, according to Mr. Birch's summary account, stated it to be "a novelty, producing fine dyes, going farther than indigo, and rivalling it, in the solidity and lustre of its colours." Fortunately for Mr. Birch, he did not, on the strength of this report, precipitately engage in an extensive manufacture of this article, as he might have done, if my opinion had been equally favourable. One of his letters contains this observation: "Dr. Bancroft's experiments, and remarks, appear to have been made with much good sense, candour, and kindness; had he given as favourable an opinion as Dr. Higgins, I should have had more dependence than I can now have, &c."

Mr. Birch did not, however, relinquish this object, until by sending to this country several parcels of the Barasat Verte, and getting it used by dyers, he became fully satisfied, that it had no other value than that of the indigo contained in it; and that, *as indigo*, this was not the most advantageous form, or method of preparing it.

The manufacture of this dye being now abandoned, I may, without impropriety, intimate my belief, that the Barasat Verte was obtained from the *taroom akkar* of Mr. Marsden, (lately mentioned at p. 140,) which Dr. Roxburgh has denominated asclepias tinctoria, (belonging to the natural order of contortæ,) and which was introduced at Calcutta, a little before Mr. Birch produced the Barasat Verte. What the latter mentions of its leaves, p. 198, agrees with Mr. Marsden's account of them; and Mr. Birch's observation, that the seed did not vegetate in Bengal, is conformable to Dr. Roxburgh's remark, that it did "*not ripen its seed*" in the botanic garden at Calcutta, nor in that of Samulcota. (See Trans. of the Society of Arts, &c. vol. 28, p. 302.) The latter also mentions *hot* water, as necessary to extract the colouring matter of the leaves of the taroom akkar, which enables us to understand why Mr. Birch has included fire among the means employed to prepare the Barasat Verte. Probably this "stately useful creeper," as Dr. Roxburgh terms it, contains a larger proportion of extractive matters, than other plants yielding indigo, (which the hot water would copiously extract,) and the precipitants employed by Mr. Birch, may have been such as to throw these matters down abundantly, intermixed with the indigo.

Dr. Roxburgh describes another species of swallow wort, under the name of asclepias tingens; which is, he says, "a large twining shrubby plant, brought from *Pegu* in 1795, to the botanic garden at Calcutta, where it thrives well." He adds, "Dr. Buchanan, who brought the plant, informed me, that from its leaves the *Burmah* people prepare a *green* dye."—"I have made, (he adds) a variety of experiments with the view of obtaining the green dye above mentioned, but without success."—"But this information is from so respectable a source,

as to induce me to hope, some better qualified person may be able to discover how this green dye is to be obtained and applied." See Trans. of the Society of Arts, &c. vol. 28, p. 305.

Formerly the *soot* of burnt wood was employed substantively to dye woollen cloths of an olive green colour; though it seems now to be rarely used. It gave cloth an unpleasant smell, which was, however, in some degree compensated, by the certainty with which the cloth was afterwards thereby preserved from the depredations of moths.

Turmeric.

Of substantive vegetable yellows, the only one employed in Europe, and deserving of notice, is the root of the Curcuma, or Turmeric; which, without any addition, yields a fine bright colour, though of but little durability. Of this there are two species, the Rotunda and the Longa. The latter is very generally employed in the East Indies, as a condiment with animal food. The former, or *round* root, is chiefly cultivated for dyers' use. Loureiro, after mentioning both species as growing wild, and also by cultivation, in China and Cochinchina, adds, concerning the round, "radix ista non est esculenta: ad tingendum adhibetur colore *quidem pulchro*, sed inconstante." (Tom. i. p. 9.)

This beautiful colour has not the smallest affinity for any metallic or earthy basis. I have applied solutions of alumine, tin, iron, and all the other metals, in *spots*, to calico; and after drying and rincing, have dyed it with turmeric, which, unlike any of the adjective colouring matters, was imbibed *most* copiously upon the parts which had received *no basis* or mordant; and the colour being exposed to the sun and air, it did not prove more fugitive upon these parts, than on those to which alumine,

tin, iron, &c. had been applied. It is worthy of remark, also, that the colour itself was not altered by any basis.

In 1793, Mr. Bayley, who was extensively engaged in dyeing silk handkerchiefs to imitate those of India, informed me, that the yellow spots in these handkerchiefs were all produced by a tincture of Turmeric, made by digesting six pounds of the powder (of Turmeric) in a gallon of malt spirit, and afterwards, by a *press*, separating three quarts of a rich tincture, which cost about four shillings the quart, and was applied topically, and without thickening, to parts or spots of the silk handkerchiefs, which in the dyeing had been *reserved white* by the usual means.

I found that a tincture of turmeric obtained in this way, and gummed, when applied topically to calico, produced a beautiful yellow, which, by washing with soap, was made *red;* but being well rinced, and exposed to atmospheric air, it again became yellow; and in this way would bear several washings.

Mr. Clarkson, in his Essay on the Impolicy of the African Slave Trade, relates that "a gentleman, resident upon the coast, (of Africa,) ordered some wood to be cut down, to erect a hut: whilst the people were felling it (continues Mr. C.) he was standing by, and, during the operation, some juice flew from the bark of it, and stained one of the ruffles of his shirt. He thought that the stain would have washed out; but, on wearing it again, he found that the yellow spot was much more bright and beautiful than before, and that it gained in lustre every subsequent time of washing." Pleased with the discovery, he sent home a small sample of the bark, which "produced a valuable yellow dye, *far beyond any other ever in use in this country.*"

Mr. Clarkson adds, that this gentleman "is since unfortunately dead, and little hopes are entertained of falling in with the tree again." The colour mentioned in this account, if there be no error in it, must have been of

that kind which I have denominated substantive, as capable of being fixed by dyeing, &c. without the aid of any aluminous or other basis.

M. du Pratz, in his history of Louisiana, also mentions a tree, or shrub, seldom exceeding the thickness of a man's leg, the wood of which, he says, is yellow, and yields a juice of the same colour, if cut in the sap. Both the wood and the juice, he says, have a disagreeable smell; and the former is used by the natives for dyeing, first cut into small pieces, and boiled in water, into which they dip feathers, hair, &c. He calls it ayac, or stinking wood; and as he mentions nothing of the use of alum, or any other basis or mordant, this, if his account be accurate, must also be a substantive colour. I fear, however, that the information of persons, not particularly acquainted with the subject, cannot be much relied upon respecting the natures and properties of dyeing drugs.

The roots and bark of the Berberis vulgaris, Linn. or Barberry shrub, are naturally of a fine yellow colour, which they communicate to wool, *without any basis;* but it has not the smallest degree of permanency against the action either of air or soap. This shrub indeed furnishes a remarkable instance, to show how little can be discovered respecting the colouring properties of plants from their external appearances. A similar instance lately occurred to me in the wood, bark, and root, of the Zantoxylum clava Herculis, Linn. (the tooth-ach tree, or Japan pepper tree,) every part of which is strongly coloured of a most beautiful yellow; but having procured some of it for trial, I could extract but little colour from it, notwithstanding its seeming abundance of tingent matter; and the little which I did extract, was, like that of the Berberis, utterly incapable of forming the least union with any basis, or of resisting the action of air, or of soap, in any degree.

In a note to p. 136, I have referred to a letter from Dr. Roxburgh, mentioning that he had sent from India, for trial by me, a parcel of "the coloured tubes of the blossoms of nyctanthes arbor tristis, Linn. which the Hindoos employ to give a most beautiful but fugitive orange colour to cotton;" and I found that these tubes, by mere infusion, even with cold water, yielded such a colour as Dr. Roxburgh has described, and that it took readily upon cotton and silk, by mere cold maceration; but it had no affinity or attraction for alumine, the oxides of tin, iron, or any other basis, or mordant; and I therefore conclude, that, in the present state of our knowledge, there is no probability of rendering it permanent; though, as a substantive colour, it resisted the sun and air, for a very few days, on calico, and for a week on silk, and disappeared gradually, rather by losing body, than by any degradation or change of its tint: strong muriatic acid did not appear even to weaken the colour, but it was immediately discharged by undiluted nitric acid, leaving the calico perfectly white: oil of vitriol had less action on the colour, though it burned holes on the dyed cotton; it was not changed by washing with soap.

Annotta.

The seeds of the Bixa Orellana, Linn. (growing spontaneously in different parts of Guiana,) are covered with a reddish pulp, which is collected and sent to Europe in different forms, under the names of annotta, arnotta, and roucou. It is principally employed for dyeing silk, and sometimes for cotton; though its colour, by all the ways and means of applying it, hitherto discovered, is so fugitive, that perhaps it would be better if it were never employed, even for dyeing silk. It partakes so much of a resinous nature, as to dissolve but very imperfectly in water; and therefore at *least* an unequal weight of potash

is employed to render it soluble in that vehicle, and afterwards the silk or cotton is dyed therein without any aluminous or other basis.* The colour of annotta becomes less red, and more inclined to the orange, when separated from the seeds by maceration, in water, as is usually practised; and by the addition of potash, it is made to incline still more to the yellow hue. This last change may, however, be readily overcome by adding any of the different acids to the dyeing liquor, after sufficient colour has been taken up, by the silk or cotton dyed therein; and afterwards prolonging the dyeing for a quarter of an hour: argol or tartar is generally preferred for this purpose, because it not only raises the colour, but seems to render it a little more fixed; so much of it should be used, as to make the liquor moderately sour. It is remarkable, that though the colour dyed with annotta fades very fast by exposure to air, it resists soap, and the action of acids, better than some colours which are much more permanent. And it certainly affords one, among several instances, of colours which decay by causes very different from combustion; because linens and cottons, dyed in the usual ways with annotta, suffer less than madder colours from the oxymuriatic acid. The fresh pulp of the Bixa Orellana, taken immediately from the shrub whilst growing, and applied to cotton without the addition of any alkali, seemed to afford a colour more lasting, and approaching nearer to the red, than that dyed from the pulp, separated by maceration, as in the common annotta.† The greatest consumption at present of

* The liquid sold in different parts of the town, under the name of "Scott's Nankeen Dye," appears to be nothing but an alkaline solution of this drug.

† M. Leblond has proposed (Ann. de Chim. tom. 47) to separate the colouring matter from the seeds of the Bixa Orellana, simply by washing them with water, and after precipitating the coloured

this article, at least in Great Britain, is, in giving to cheese a kind of yellowish orange tint, for which it is very suitable, as being harmless, and nearly tasteless.

The Lawsonia inermis of Linn. has long been used throughout India, Persia, Arabia, Egypt, and in many other parts of Africa, for giving a reddish stain to the nails, lips, &c. It is the Ligustrum Ægyptiacum of Prosper Alpinus, and the Hinna of the Arabians. Sir William Jones relates, that being at the island of Hinzuan or Johanna, and observing a very elegant shrub, about six feet high, not then in blossom, he learned, that it was the "Hinna," of which he had read so much in Arabian poems. "Musa (one of the inhabitants, says he) bruised some of the leaves, and having moistened them with water, applied them to our nails, and the tips of our fingers, which in a short time became of a dark orange scarlet."—Nieuhoff says, they prepare the tincture by steeping the leaves after they have been rubbed small upon a marble stone, in fair water, mixed with a small quantity of lime."—"With this (continues he) the Turks and Persians also dye their horses' tails." This shrub, according to Adanson, is called foudenn, by the negroes of Senegal, where it is used, both by the men and women, to give their nails a red stain, which lasts until the substance of the nails changes by growth. As the colour of this shrub requires no kind of basis or mordant, it must naturally belong to the class of substantive colours.*

matter by lemon juice or vinegar, to render it dry and hard by evaporation; and Vauquelin having made experiments with the colour so prepared, concludes it to be worth, at least, four times as much as the common annotta.

* This account of the Lawsonia inermis, was published in 1794, before I had seen any of it. But in 1801, my son, being in Egypt, as physician to the British army there, sent me several packages

I lately received a few ounces of small seeds, inclosed in a flea-coloured husk, but without any information respecting the plant on which they grew. They were brought from the coast of Barbary, where, as I was informed, they are used in dyeing red or pink colours. In two or three small trials which I made with them on silk, they appeared to possess a substantive colouring matter, similar in some respects to that of safflower. At first I thought they might be the seeds of the gardenia florida, which, according to the accounts of Mr. James Cunningham, who formerly travelled into different parts of the East Indies in pursuit of natural curiosities, the Chinese employ for dyeing *scarlet*, under the name of *unki*.* I

of the leaves, dried and powdered; and by the experiments which I have since made with this powder, I am inclined to think, that it ought to be removed from its present arrangement, and placed among the adjective colours. For though great quantities of it are employed substantively as a dye, it has a decided affinity for the basis of alumine, and that of iron, giving with the former a permanent orange-brown to calico, and with the latter a brownish black.

Sonini represents the dried leaves of this plant, as a valuable orange or reddish dye, and says, that 14 or 15 ships were annually loaded with them at Alexandria, and sent to Constantinople, Smyrna, and Salonica, whence a part was exported, particularly to Germany, and there used "in dyeing furs, and the preparation of leather."

Another species, which is *thorny*, possesses the same tingent property. Hasselquist says, the practice of dyeing the nails with the Lawsonia spinosa (alhenna,) is so ancient in Egypt, that he has seen the nails of *mummies* dyed therewith. He adds, that the powdered leaves are annually exported in great quantities.

Loureiro says, of the Lawsonia spinosa, "foliis contritis admixta calce, utuntur Cochinchinenses, ad tingendos ungues colore ruberrimo: qui mos pro elegantia invaluit non solum apud alios populos Indianos, sed etiam apud Turcas, Persas, Æthyopes." Tom. i. p. 229.

* Dr. Plunkenet, in his Amaltheum, page 29, says, "Semina tinctoribus inserviunt iis enim ab indigenis Sinensibus optime tingitur nobilis ille color, quem *escarlatinum* nostrates vocant, ut

found, however, that this could not be the case, as the seeds of the gardenia grow inclosed, several of them in one common capsule, involved in a rich-coloured mucilaginous substance; whereas the Barbary seeds evidently grew without any such inclosure. I cannot discover whether the seeds of this gardenia, or the mucilage surrounding them, ought to be considered as a substantive or an adjective colouring substance; all accounts being defective in this respect.*

Safflower.

This is the Carthamus tinctorius, Linn. which is cultivated in the southern parts of Europe, Egypt, &c. and also in the East Indies, whence considerable quantities of it have been lately imported to Great Britain. There

nos monuit vir multiplicis industriæ atque indefessi laboris hac in parte, D. Jacobus Cunninghamus."

* When the late Sir George Stanton returned from the embassy to China, in which he was associated with Lord Macartney, he gave me some yards of a cotton cloth, which had been dyed scarlet, and probably from the gardenia florida, (now called cape jasmine in this country.) It was one of the articles mentioned by Mr. Barrow in the following words, viz. "among some of our presents were also *pieces* of a *beautiful scarlet*." (P. 560.) The colour of the cloth so given to me, certainly approached nearer to the cochineal scarlet than any which I have seen dyed on cotton, in Europe, and it seemed to be of a resinous nature, dyed substantively without any basis, and capable of bearing exposure for a reasonable time to the sun and air, but liable to be in a considerable degree discharged by washing with soap. Concentrated oil of vitriol had but little effect upon this scarlet.—Strong muriatic acid changed it to an orange; and double aqua fortis made it yellow. So that it was much less injured by these acids, than colours vastly more durable are known to be.

Loureiro moreover mentions another species of this genus, viz. gardenia grandiflora, whose succulent berries, recently gathered, are, as he says, (tom. i. p. 147,) employed to dye silk of an elegant red colour.

are two varieties of this plant, one of which is distinguished by having much broader leaves than the other. Berthollet mentions the narrow-leaved as that which is cultivated in Egypt, whence considerable quantities of it are from time to time exported.* It is the *flower* only of this plant which is employed in dyeing, and which affords two sorts of colouring matter, one soluble in water, and producing a yellow of but little beauty, when dyed adjectively, on an aluminous basis; the other is *resinous*, and best dissolved by the fixed alkalies: it is this last which alone renders safflower valuable in dyeing, as it affords a red colour, exceeding in delicacy and beauty, as it does in costliness, any which can be obtained, even from cochineal, though much inferior to the latter in durability.

To obtain this red colour of safflower, it should be tied up in a linen bag, and subjected to maceration and pressing in clean running water, until all the yellow colouring matter is dissolved, and washed away, and the flowers which were previously yellow, are made red by an abstraction of this yellow colour. This being done, the flowers are again to be macerated in a solution of clean soda, in quantity sufficient, and only sufficient, completely to dissolve and extract the resinous or beautiful red colouring matter; which is to be separated by draining, and the application of more water to the residuum, until the whole is abstracted and collected for use. To fit this colouring matter for dyeing, the soda by which it was extracted is to be neutralized by an acid; and for this purpose the *citric* acid is generally preferred to all others, and more especially that which is contained in lemons, or limes beginning to rot or spoil; or in their

* Niebuhr says, there are ten varieties of safflower cultivated in Egypt, and that the quantity annually produced, commonly amounted to between fifteen and eighteen thousand quintals.

juice, when it has been kept some months in casks, and the mucilage has suffered a partial decomposition. Next to the citric acid, that of tamarinds, and of tartar, are thought most suitable; though Bergman has recommended the sulphuric, as next to the citric, if it be not used in excess. But Scheffer pretends that the acid juice of the berries of the pyrus acuparia, or mountain ash, produces a better and more lasting colour than even the citric acid.

The colour of safflower will not bear the action of soap, nor even that of the sun and air, for a long time; and being more costly than even the colour of cochineal, it is principally employed for *imitating upon silk* the fine scarlet (ponceau of the French) and rose colours, which are dyed with cochineal upon woollen cloth. Beckman pretends that by preparing cotton as for the Turkey red, and dyeing it with safflower, the colour was rendered much more durable, than it is by the ordinary process; but in this way it will cost so much, and after all prove so inferior, in point of *durability*, to the Turkey red, that this method of employing safflower, does not seem likely to be ever adopted.

The fine *rose* colour of safflower, extracted by crystallized soda, and precipitated by citric acid, and then slowly dried in the shade, being afterwards finely ground with the purest talc, produces the beautiful paint by which ladies give to their cheeks the bloom of youth and health, and which the French distinguish from carmine by the name of "*rouge vegetale.*"

Aloes.

M. Fabroni, in a memoir printed in the 25th volume of the Annales de Chimie, has stated, that the almost colourless juice of the aloë succotrina angustifolia, by exposure to atmospheric air, assumed a fine purple co-

lour from an absorption of oxygene, and that he had dyed a beautiful and lasting purple with it upon *silk*, without any mordant or basis whatever; and in the 68th volume (p. 165) of the same work, M. M. Bouillon Lagrange, and Vogel, have asserted, that nitric acid, heated with powdered aloes, produced a beautiful yellow powder, which, on being mixed with water, gave to the latter, a magnificently rich purple colour: that a single atom was sufficient to colour a large portion of water, and that the colour was so permanent, that when applied to the fingers, the stain continued several days, especially if a little alkali had been previously mixed with the powder.

Encouraged by these statements I was induced, when this volume was nearly ready for a second impression, to rub, in a glass mortar, some of the best Barbadoes aloes, and pour upon it a little strong nitric acid, to which, after it had been mixed with the aloes, I added three or four times as much water; and with this mixture farther diluted, I the next day dyed some pieces of white broad cloth and calico: the latter took only a sort of tobacco colour; but the cloth soon exhibited a rich, though *brownish*, purple, of considerable brightness, and which, after exposure to the sun and air during all the month of July (1812,) had suffered no change, excepting that it seemed, perhaps, half a shade darker and fuller than at first. I conclude therefore that this colour is eminently durable. It had, however, too much of the chocolate brown in its composition to be deemed a beautiful purple. I tried a similar mixture, with a nitro muriate of tin, and with alum, but neither of them appeared to improve the colour in any way. I also tried it with sulphate of iron, which produced no change.

How far it might be practicable to render this aloetic colour strictly a fine purple, and how far, in point of

cheapness, it would be advantageous for common use, are questions which I am not yet able to answer. Perhaps the more common Barbadoes aloes, might answer as well as that with which my experiments were made. I mean soon to ascertain this fact.

Aloes powdered, and mixed with strong sulphuric acid, produced only a snuff colour upon broad cloth, and with muriatic acid, it produced only a lighter brown; the purplish colour before mentioned, is therefore an effect of the nitric acid alone.

Orchall and Cudbear.

The Linnean genus of Lichen, belonging to the natural order of algæ, contains numerous species, of which several, after being macerated with ammonia or volatile alkali, afford beautiful violet, purple, and crimson, substantive dyes; of these the most valuable is obtained from the lichen roccella, Linn., which in the quantity, vivacity, and durability of its colour, excels every other species of lichen; though unfortunately even this cannot be deemed a fast or permanent dye. Dr. Dillenius has given an accurate figure and description of it in his excellent and elaborate "Historia Muscorum," Oxonii 1741. 4to. p. 120, tab. 17, fig. 39, under the name of coralloides corniculatum fasciculare tinctorium, fusci teretis facie." And he thinks, with reason, that it is the identical τοτοντιον φυκος, or alga marina of Theophrastus, and the λειχην of Dioscorides, mentioned by them as being in great use and estimation for dyeing wool, of a colour more beautiful, when first dyed, even than the Tyrian purple.* Pliny also mentions it, as I have already noticed at p. 93, and in his 26th book, chapter 10, he calls it "Phycos thalassion;" "id est fucus marinus;" adding, that it serves

* Theophrast. Hist. Plant. iv. c. 7. p. 82. Ed. Heinsii. Dioscorid. Lib. iv. c. 95.

as a *ground* for the shell purple, "qui conchyliis substernitur:" and in his 32d book, chapter 6th, he mentions it again as one of the "algæ maris," of which, says he, there are several kinds, and among them that of *Crete* is most commended, &c. "Laudatissima quæ in Creta insula juxta terram in petris nascitur; tingendis etiam lanis *ita colorem alligans*, ut elui postea non potest." He was however greatly mistaken in thus supposing that it contributed to render other dyes more fixed or lasting.

After all knowledge of the use of this lichen had (in common with arts and sciences) been lost for several centuries in the west of Europe, it was restored at Florence early in the 14th century, by a Florentine, descended from a German named Ferro, or Frederigo, who having resided some years in the Levant, and acquired information respecting the properties of this lichen, returned to Florence, and there introduced, and exclusively enjoyed, the use of it in dyeing, for some years; and acquiring great wealth, became the founder of one of the principal Florentine families, who took the name of Oricellarii (afterwards abbreviated to Rucellarii and Rucellai,) from the name of *Oricello*, by which this commodity was afterwards distinguished in Italy: and the Italians having thus become acquainted with the preparation and uses of this lichen, engrossed for a century all that could be procured of it among the islands of the Archipelago, and on the shores of the Mediterranean, until the discovery of the Canary islands (which had likewise been lost) in 1402, by John de Bethencourt, a Norman, relieved the other nations of Europe from their dependence upon Italy for this commodity.*

* I have now before me the scarce "Histoire de la premiere decouverte et conquete des Canaries, &c." by this Bethencourt, (described as chamberlain to the French king Charles VI.) stated to have been written by two priests (Boutier and Le Verrier) who

At a much later period (i. e. about 1730) the orchella was discovered growing abundantly and luxuriantly at the Cape de Verd islands; where it had been left to acquire full maturity, unmolested, and was found to be much larger and richer in colouring matter, than any which had been previously known. The quantity had however been considerably diminished, when Wadstrom was there about half a century afterwards. The labour of gathering the orchella then cost, as he informs us, about five shillings sterling the quintal, and the medium price at Porto Praya, was about 3000 reas, (or 18*s.* 6*d.* sterling;) but when carried to Lisbon, it sold for 19,200 reas, more than six times as much. It often sells at London for 300*l.* sterling per ton, and sometimes for more than 1000*l.*

Ray, (Hist. Plant. i. p. 74,) has given, from Imperatus, a short account of the preparation of Orchella for dyeing; and Micheli has since published one, which is more circumstantial, and probably conformable to the practice of the Florentines. The means employed were human urine,

were in his suite, and published by " Galien de Bethencourt, Conseillier du Roi," in the parliament of Rouen, (printed at Paris in 1630,) in several parts of which, mention is made of this commodity, particularly at p. 130, where, in describing the productions of these islands, I find these words: " Et y croit une graine qui vaut beaucoup, qui on appelle *orsolle;* elle sert a teindre drap ou autre choses, et est la meilleure graine que l'on sache trouver en nul pais pour la condition d'icelle; et si cette isle est une fois conquise et mise a la foi chretienne, icelle graine sera de grand valeur an sieur du païs;" and in a note the following explanation is subjoined: " Orsolle graine a teindre de grand prix, oriocola ou oricola, dont se fait grande trafic par tout." Afterwards, at p. 180, I find, that Bethencourt, among other regulations, prohibited all persons from dealing in this commodity, meaning to reserve the profits of it exclusively to himself, as the kings of Spain have since done in the islands of Canary, Teneriffe, and Palma. The Canaries have since annually produced about 2,600 quintals of orchella.

and either potash or soda, with which the powdered lichen was mixed, macerated and fermented (in close wooden vessels) for several weeks, until the resinous colouring matter, by combination with the ammonia of the urine, had been sufficiently evolved and dissolved: after which, it was preserved in a moist state in tight casks, sprinkling the surface, when necessary, with urine or lime water, until wanted by the dyer. Lime has since been substituted for potash and soda, as several other species of lichen have been for the rocella, or orchella, though none is of equal value or utility. One of the best of these substitutes probably is a lichen, which Imperatus has described and figured, (Hist. Nat. xxvii. cap. 11,) as growing on rocks near the sea in *Candia*, and there called *rubicula;* it is nearly related to the orchella, and frequently mixed with it. Linnæus has named it lichen fuciformis. It grows also in the East Indies.

The French have for several centuries employed in this way, a species of lichen called by them *perelle* from a corruption of the word *pierre*, (stone), it being commonly found adhering to volcanic stones, or productions; and it has been generally supposed and stated to be the lichen parellus of Linn., but it appears certain, from a "Memoire" by M. Cocq, just published in the 81st volume of the Annales de Chimie, that this is a mistake; that in Auvergne, where this lichen is principally gathered, the true lichen parellus of Linnæus is called la pommelée, and that this is constantly rejected by the persons employed to gather the *perelle*, as being unfit for their purpose: and indeed M. Cocq found, by suitable trials, that the lichen parellus of Linn. would only yield "un chamois rougeâtre." And he asserts most positively, that the moss collected and employed to produce l'orseille d'Auvergne, (sometimes also called orseille de

terre) is the variolaria orcina of Acharius,* (which Dr. Westring has mentioned as affording a beautiful colour;) that this is generally, and invariably denominated *perelle* in Auvergne, and that, when prepared in the usual way, it afforded " la belle et vive couleur rouge *amarante*, qui les teinturiers du pays en tirent." It sells he says in Auvergne, for between 12 and 24 sols the pound, and a labourer may gather four pounds daily. M. Chaptal says, the English used to obtain it on the coast of Italy, (probably at the isle of Elba.)

M. Cocq gives, in the same memoire, a particular account of the process by which the *perelle* is prepared for dyers' use, at *Clermont;* he having been extensively engaged in that business for several years. It appears that wooden troughs are employed as usual to macerate and ferment the *perelle:* that these troughs are commonly about six feet in length, two or three in breadth (but narrowest at bottom,) and about two feet in depth; and that to each trough a cover is exactly fitted, so that it may retain as much as possible of the volatile alkali of the (human) urine; of which 240lbs. are commonly employed for every 200lbs. of the perelle; this last being the quantity usually allotted for each trough, and which it will about half fill. In such a trough the perelle and urine are to be well mixed, and afterwards stirred every three hours, during two days and nights, taking off the cover *only as often*, and as *long* as is necessary for the stirring. On the third day 10lbs. of sifted and slack lime are to be added, and well mixed, together with a quarter of a pound of arsenic, and as much alum. The workmen are to avoid the fumes of the arsenic as much as possible, for some hours after its admixture.—But when there is no longer any danger from these fumes, the stirring is to

* Meth. Lich. suppl. p. 6.

be repeated several times, once each quarter of an hour, and afterwards at the intervals of half an hour, until the fermentation is established; after which the mixture need only to be stirred often enough to hinder the formation of a crust on the surface, which, by obstructing the fermenting process, would hinder a complete formation and evolution of the colour. When the fermentation has subsisted 48 hours, it commonly begins to slacken, and is then to be excited by an addition of 2lbs. more of sifted lime, and the stirring repeated once every hour until the fifth day, when the frequency of stirring may afterwards be gradually diminished. On the eighth day, there will be a considerable, but not a complete manifestation of the colour; and, therefore, the operation is to be continued a fortnight longer, (stirring the mixture at intervals of six hours;) and even after this, it is commonly thought safest and best to extend the process another week, making in all a lunar month; though when the perelle is rather deficient in colouring matter, three weeks will fully suffice.

The colouring matter so produced, is afterwards to be kept *moist* in closed casks, in which it will improve during the first year; remain stationary during the second, and begin to decline in quality afterwards. When the volatile alkali has evaporated, the *orseille* (as it is called when so prepared) acquires an agreeable violet smell, and by simple boiling it will, says M. Cocq, dye upon cloth "*un amarante;*" and with longer boiling "*un amarante foncé.*" I shall presently offer some observations upon this process, when treating of the preparation of *Cudbear* in this country.

During many years, perhaps several centuries, the inhabitants of Sweden, Scotland, Ireland, Wales, and some of the northern parts of England, have employed different species of lichen, macerated with urine, in their domestic

dyeing.—One of these, the lichen omphalodes, Linn. has been commonly called cork, corker, and arcel; and in Wales kenkering; and it gave a kind of dark crimson to wool and woollen stuffs. It is the lichenoides saxatile tinctorum foliis purpureis of Ray. (Synops. p. 74, No. 70.) Linnæus says, (in his Flora Lapponica) that an immense quantity of this lichen grows on the island of Aland, in the Baltic.

The lichen calcareus, Linn., or lichenoides tartareum tinctorium candidum tuberculis atris of Dillenius, (p. 128) which grows exclusively on limestone rocks, possesses similar properties, and has been long used in the same way, by the people of Wales, the Orkneys, &c.

Nearly similar colours may be obtained from several other species of this genus, (by maceration with lime and urine), particularly the lichen saxatilis, Linn. (or lichen de roche of La Marck, Flor. Franc. p. 78); the lichen caperatus, Linn., lichen pustulatus, Linn., lichen argentatus, Linn. (called cadlog, and kengevin, in Wales); lichen stygius imbricatus, &c. Linn., lichen nivalis, Linn., lichen deustus, Linn., lichen fistulosus of Hudson, and lichen muscorum of Hoffman; which, Kalm says, the Pennsylvanians macerate three months in urine, and then dye with it a beautiful red colour.

But the most important of all the lichens produced in the northern parts of Europe, seems to be the lichen tartareus, Linn., a crustaceous moss, growing commonly on lime-stone rocks, in Sweden, Scotland, the north of England, &c. It is the lichenoides tartareum farinaceum scutellarum umbone fusco of Professor Dillenius (p. 132.) Linnæus mentions, (Iter West-Goth. p. 170) that the people of West-Gothland prepare a beautiful crimson dye from this lichen, which, under the name of byttelet, is used all over Sweden; and, besides this use, Dr. West-

ring computes, that about one hundred and thirty tons of it have been *annually* exported from that kingdom, since the year 1770. This is the lichen, with which a purple or violet-coloured powder is prepared in Great Britain, and sold under the name of *cudbear;* a name given to it by the late Dr. Cuthbert Gordon, who, having obtained a patent for this preparation, chose, in this way, to connect it with his own first name, which had been the maiden-name of his mother.

Having never seen Dr. Gordon's specification of his invention, I do not know the *peculiar novelty* by which it was distinguished—perhaps it may have been that of giving the preparation a *dry* instead of a wet form; or the circumstance of employing ammonia, obtained by *distillation* from urine, instead of the urine *itself*, to extract and raise the colour of the lichen; a change which, whether made by him or not, certainly was a considerable improvement, as urine contains many other matters, which, at best, are but an useless incumbrance to the volatile alkali.

At the proper times and places, one person may collect twenty or thirty pounds weight of this lichen daily; but it should be allowed five years growth before it is gathered. It commonly sells at the port of London for twenty pounds the ton: but, to prepare it for use, it must be washed and dried; and by these operations the weight is commonly diminished one half, and the price, in effect, doubled. It is macerated and stirred in wooden troughs or vessels with covers, as is practised with the perelle at Clermont, in Auvergne, only substituting an *aqua ammonia*, obtained by distilling human urine, that of graminivorous animals being deficient in the volatile alkali; the purity of which seems to be of more importance to the beauty of the colour, than is commonly sup-

posed.* I have prepared this colour several times, and am convinced, that the alum, mentioned by M. Cocq, is completely useless—and that the arsenic is both useless and dangerous; indeed, I believe the latter is not employed in this country. It seems to me, also, that much labour in stirring, and much waste of volatile alkali might be saved, by employing hogsheads instead of fixed troughs or wooden vessels. The lichen ground in a mill, properly constructed, might be put with the aqua ammonia into the bung-hole, purposely made a little larger than common, and the bung being applied and secured, so as to hinder any leakage, the hogsheads might be roll-

* Of this fact a decisive proof lately occurred to me, in consequence of an application from certain manufacturers of cudbear, in the neighbourhood of London, who complained, that they were unable to obtain more than half the usual price of that article for the produce of their own manufactory: and, being unable to discover the cause of its manifest inferiority, they requested my assistance to remove its defects. For this purpose, they supplied me with parcels of the lichen which they had commonly employed, both in its washed and unwashed state; and also with some of their aqua ammonia, and I soon satisfied myself that the latter had alone occasioned the defects of which they complained. In making use of it, I found, that after the predominant odour of the ammonia was a little dissipated, another became, and remained prevalent, which was extremely offensive, and seemed to be the very essence of the volatile parts of solid human fæces: and I learned upon enquiry, that no pains had ever been taken to separate this ordure from the urine, with which it was frequently intermixed in their collections. To ascertain the difference occasioned by this offensive addition, I macerated a parcel of the lichen with it, in the usual way, and another parcel in pure aqua ammonia, which I procured from a druggist; and with the latter I produced very excellent cudbear, which, both in its appearance and in its effects, when applied to cloth, was equal to the finest sample which I could procure, while that produced with the impure volatile alkali, before mentioned, was *manifestly very defective*, in the look, as well as in the colour dyed from it.

ed from time to time, so as completely to obviate all need of stirring, and all opportunity for the escape of volatile alkali, which is unavoidably very great, every time the troughs, &c. are uncovered for that operation.

The colours obtained in this way, from the several species of lichen, though possessing great beauty and lustre at first, are so fugacious, even when dyed upon wool, that they ought never to be employed, but *in aid* of some other more permanent dye, to which they may give body and vivacity; though some dyers have been tempted, by a love of gain, to employ the cudbear alone; and in one instance, a great corporation lately obtained from a London dyer, the restitution of several thousand pounds, as a compensation for excessive prices paid to this dyer for colours which ought, and were believed, to have been dyed from indigo and cochineal, though they had, in fact, been dyed from cudbear only.

I have already mentioned, that the colour obtained from the orchella is less fugacious and more beautiful than that yielded by any other species of lichen, and it is, therefore, much more costly. The application of these colours by dyeing is so simple and easy, that no instruction can be wanted from me on that subject. Its purple or violet tint is the immediate result of the union between the resinous colouring matter of the plant, and of the ammonia with which it is prepared; and it may be made crimson, by an admixture of, I believe, any of the acids. Alum does not in any degree render the colour more permanent; but the nitro muriate of tin is believed to produce a better effect in this respect, though it makes the colour dyed with it, approach nearer to the crimson; but I have never found that it was attended with any additional vivacity.

Cudbear in this country is chiefly employed to give

body and brightness to the blues dyed with indigo, and produce a saving of that article; it is also used as *a ground* for madder reds, which commonly incline too much to the yellow, and are made *rosy* by this addition. It stains marble durably, as was first observed by Dufay.

But though, as I have lately mentioned, the purple, or violet colour obtained from these lichens, depends upon a combination of ammonia, the presence of a certain portion of oxygene also is necessary to its existence, as I have already noticed at p. 47, in regard to the colour of the spirituous thermometers. Water, coloured by prepared orchella or cudbear, and secluded from atmospheric air, loses its purple in much less time than the spirituous tincture; and I found, that a phial being filled with it, and with a small proportion of muriate of tin, recently prepared, and closely stopped, the purple colour of the cudbear completely disappeared in less than two minutes, as I presume, by an abstraction of its oxygene. This is analogous to the extinction of the colour of sulphate of indigo by the same muriate.

Besides the lichens, whose colour depends upon a combination with the ammonia, there are some which afford substantive colours, less beautiful, indeed, but more durable, by mere boiling with water—one of these is the muscus pulmonarius of Caspâr Bauhine, or the lichenoides pulmonium reticulatum vulgare marginibus peltiferis of Dillenius, (p. 212) called Rags, and Stone Rag, in the northern parts of England; which, without any mordant, dyes a very durable dark-brown colour upon white wool or cloth; and a *fine lasting black* upon wool or cloth which has previously received a *dark blue* from indigo.

Besides the lichens affording substantive colours, there are many which, being employed *adjectively* with alum, or the oxides of tin and iron, are capable of dying yel-

lows, olives, and a variety of browns—but they do not belong to this division of my subject—and as similar colours may be given at less expense, with other means, I probably shall not notice them hereafter; but think it sufficient to refer those who may wish for more information concerning them, to Hoffman's "Commentatio de vario Lichenum usu," printed at *Lyons*, 1787.

There is a species of colouring matter diffused, in greater or lesser proportions, through the barks and other parts of almost all trees and shrubs, and which, without any basis or mordant, permanently dyes or stains wool, silk, cotton, and linen, of that particular kind of colour, which the French call "fauve," (fawn-colour) and sometimes couleur de racine, ou de noisette, (root, or hazel-nut colour.) This being naturally blended with some of the more valuable colours of vegetables, frequently does harm, by degrading or obscuring them. It is found most abundantly in the peelings, rinds, or husks of walnuts, (Juglans regia), in the roots of walnut-trees, in alder bark, &c.; and it seems to acquire both body and permanency, by attracting and combining with pure air. M. Berthollet has, however, treated so fully and so well of the properties of this kind of colouring matter, when applied substantively, that I cannot do better than refer my readers to that part of his work which relates to it; observing, at the same time, that the colouring matter in question, though capable of being permanently fixed without any metallic or earthy basis, does, in some instances, acquire new and more useful properties, when applied with a basis adjectively; which I shall notice hereafter, under the proper heads, and particularly when I come to treat of the black dye.

There are three species of poisonous shrubs, or vines, growing in North America, and containing in their stems, leaves, &c. a white milky juice, which, when applied to

linen, cotton, or silk, produces a stain, which soon becomes of a full, strong, and durable *black colour*, incapable of being discharged by repeated washings, or impaired by the weather. These are the Rhus vernix, (growing likewise in Japan, and yielding the fine Japan black varnish); the Rhus radicans; and the Rhus toxicondendron, Linn. Some trials, which I formerly made in America, seemed to indicate the last of these as affording the deepest and most permanent black. But in all of them this colour probably depends on the addition of oxygene to the colourable matter; an addition which, in the formation of indigo, produces only a blue, whilst in the present instance it changes a white milky juice to the greatest possible extreme, by rendering it of a full strong black. I have found that by washing the stains before the black was completely produced, it never attained more than a blackish brown.

Marking Nut. Or Semecarpus Anacardium.

The tree which Linnæus erroneously denominated Avicennia Tomentosa, and which his son afterwards, with more propriety, called Semecarpus Anacardium, produces a nut, which has been long known under the name of Malacca bean, or *marking* nut, from the use generally made of it throughout India, to mark calico and silk. The shell of this nut is composed of double laminæ, between which are many cells filled with a corrosive resinous juice, of a pale *milky* colour, until the nut has ripened, and then it becomes a brownish *black*. It is only soluble, as far as my knowledge extends, by the *combined* operation of alcohol and *caustic* alkali, neither of which, *alone*, will dissolve it; and being dissolved, it may be made to serve as an ink, probably of great durability, and indestructible by any thing which will not also destroy paper. Osbeck says, that when the juice

is employed for marking, the letters are commonly covered, *while wet*, with quick lime, to obviate the injury that might otherwise result from the corrosive property of the juice; and it seems that quick lime is very generally employed for this purpose, in the way mentioned by Osbeck, or mixed with the juice before its application. By long keeping, this juice becomes as thick as tar, and in some of the nuts which were given to me, by a gentleman in whose possession they had been for more than ten years, it manifested no acrimony to the taste. Some of it being topically applied to white calico, without any addition, it penetrated thoroughly, and, being dried, it was afterwards boiled with soap, and exposed to the sun and weather, during two months, in which space the black colour had become deeper and more decided, as I presume, by an absorption of oxygene; but as, from the viscidity of the juice, a redundance of colouring matter had been applied, the marks seemed rather to have been *painted* than stained or dyed.

Dr. Roxburgh says, these nuts are employed by the Telinga physicians, to cure the venereal disease. They are also pickled like olives, whilst very young, and, when nearly ripe, are applied as a mild caustic to sores, &c. Lamarck, and the French botanists, have restored to this tree, the name of *anacardium*, by which it was first distinguished, from the resemblance of its nut to the shape of a *heart* (somewhat flattened); and taking away this name from the *Cashew* tree, to which it ought never to have been applied, (as its nuts are *kidney* shaped,) they have denominated the latter cassuvium pomiferum, which is the name formerly given to it by Rhumphius.

Being at Barbadoes in the year 1805, a parcel of these nuts was given to me by Mr. Simmonds, a very pro-

mising young botanist, (then in the family of the governor Lord Seaforth,) who was prematurely stopped in his pursuit of knowledge, soon after, by death, at Surinam. These nuts had been recently gathered, having grown on a tree in the garden of the government house, (*pilgrims*,) but were necessarily abortive, there being no male tree on the island. Their juice I found sufficiently fluid, though only of a dark-brown colour, when spread either on calico or paper, but it afterwards became *black*, by exposure to atmospheric air. Strong nitric acid changed it to an orange; but oil of vitriol did not alter, though it weakened the colour, and this was the case when muriatic acid was applied to it. Muriate of tin produced no sensible effect upon it. This juice was a little acrid to the taste.

There are a considerable number of other vegetables, whose juices by simple topical application permanently stain linen or cotton, and the stains, by exposure to the atmosphere, generally become black, or nearly so. One of these is the amyris toxifera, or poison ash, which Catesby (vol. 2, p. 40,) has described as a "toxicodendron foliis alatis fructu purpureo," &c. adding, that "from the trunk of this tree distils a liquid black as ink, which the inhabitants say is poison." "It grows usually on rocks in Providence, Ilathera, and other Bahama islands. It is also found in South Carolina and Georgia."

The camocladia integrifolia, called Burnwood, or Papau wood, and by some Maiden plumb, in Jamaica, abounds in a moderately glutinous sap, which, as Jacquin asserts, will grow black by exposure to atmospheric air, and stain the hands of a deep black colour, only to be removed, with great difficulty, by washing with soap.

Another species of this genus, the camocladia dentata, growing in South America and in Cuba, emits, when wounded, a viscid milky juice, smelling like human excrement, which, by exposure to the air, becomes black, and gives durable stains to linen, &c. as well as to the fingers. It is mentioned by Ulloa under the name of *guao*.

Another species of this genus, Camocladia punctuata, or dotted stalked Eclipta, grows in the West Indies, and contains a thin greenish sap, which turns black by exposure to the air, and may be used as ink. Jacquin says, the negroes sometimes endeavour to increase the blackness of their skins by washing with this juice.

The Eclipta erecta (cotula alba, Linn.) affords a juice which the inhabitants of Cochin China, as Loureiro asserts, (p. 505,) employ to dye human and other hairs permanently black, and, therefore, call it ink plant; "herba atramenti."

Several species of the genus Rauwolfia abound in a glutinous milky juice, which blackens by exposure to the air, and gives lasting dark-coloured stains; one of these, R. canescens, ("le bois laiteux fébrifuge," of Pouppée des Portes,) bears juicy black berries, which, at maturity, may be used as ink, without any preparation, and are said to give a lasting black stain to linen.

The hippomane mancinella, or manchineel tree, contains a very acrid juice or sap, which, if in cutting the tree, or otherwise, it falls on linen, soon produces a black stain, which afterwards becomes a hole, from the caustic quality of the sap: probably lime would correct this, as it does that of the juice of the marking nuts.

The terminalia vernix of Lamarck, (Tsi-Chu of the Chinese,) contains, in every part of it, a caustic milky

juice, which, exuding from the tree when wounded, thickens and becomes black like pitch, by being in contact with the air, and is used by the Chinese as a varnish for furniture.

I could mention several other vegetables with similar properties, but believe it to be unnecessary.

CHAPTER VI.

Of Mineral Substantive Colours.

"Rien n'est plus facile dans les sciences fondées sur l'expérience que de multi-
"plier les faits particuliers; mais ces faits ne sont dignes d'attention, que lorsqu'ils
"servent à conduire à des vérités générales, ou que présentant, au contraire, des
"singularités nouvelles et imprévues, ils deviennent un objet de recherches." HIST. de l'ACAD. RE, &c. 1777.

EACH of the metals and semi-metals is capable, when dissolved, of becoming a basis or mordant, for fixing and modifying some at least of the different adjective animal or vegetable colouring matters, with more or less advantage, by dyeing. But besides this property, which will be made a subject of future consideration, several metals and semi-metals afford coloured solutions or oxides, which are capable of being united and fixed directly in the fibres of linen, cotton, silk, or wool, and of thereby producing various permanent substantive colours. It is indeed true, that hitherto but few metallic preparations, excepting those of iron and copper, have been used in this way, or for this purpose; I mean that of giving substantive colours.

Iron.

This, by whatever means dissolved, possesses so much affinity to linen and cotton,* that when applied to them, its oxide or calx decomposes and fixes itself permanently in their fibres, and thereby produces colours,

* The affinity between cotton and the oxide of iron is so strong, that by simply moving the former about in water, wherein the sulphate of iron has been dissolved, and left exposed to atmospheric air for a few days, it will gradually attract and take to itself every particle of the metallic oxide.

differing considerably from each other, according to the different states in which the oxide may have been applied, particularly in respect of the portion of oxygene combined with it. But as the oxide of iron, in *all states*, and *however obtained*, is disposed to attract the oxygene of the atmosphere, its different colours, by this addition, soon lose their peculiar shades or variations, and acquire the rusty colour commonly called *iron-mould.* This addition, moreover, soon renders the oxide in some degree corrosive, and joined perhaps to the rigidity which it occasions by a sort of concretion in the fibres of wool, silk, cotton, and linen, it disposes them to become brittle, or less durable. There are few, if any, who have not observed instances of this effect from spots of what is called iron-mould on linens, &c. which produce holes, long before any occur in other places. But where iron is used in dyeing, merely as the *basis* of animal or vegetable colouring matters, these last, by combining with its particles, lessen their disposition to attract oxygene, and by keeping them farther asunder, so far prevent their concretion, as in a considerable degree to obviate the rottenness in question; though there is but too much reason to fear, that even in this way, stuffs dyed with a ferruginous basis or mordant, are less durable from that circumstance; and it probably is from the use of this metal, that the rottenness so generally complained of, as accompanying the black dye, principally results.

But in this place I am only to notice the use of iron, as affording substantive colours; and for these, its use is confined to linens and cottons, to which its oxide is very frequently applied, topically, in calico printing, to produce *partial* buff, or rusty yellow, stains or figures, and, in *general* dyeing, to produce imitations of the nankin brown, as well as a considerable variety of buff

colours; for all which purposes, the solutions of iron by vegetable acids are preferred, as being least corrosive, and therefore least hurtful to the fibres of linen and cotton.

Among the vegetable acids, that of vinegar, or alegar, was for a long time almost exclusively employed to dissolve iron, and make that preparation which has been commonly denominated iron liquor (acetite of iron). But, within a few years, another acid has been very frequently substituted for the former; viz. the pyroligneous, distilled from wood. M. Chaptal justly considers this as being truly an *acetic* acid, in combination with a portion of empyreumatic oil, which, instead of diminishing, increases its utility for most of the purposes of dyeing, and especially for that of dissolving iron;* and when so dissolved, its oxide may be obtained at different degrees of oxidation, but its union with the fibres of linen and cotton, and the colours thence resulting, are most permanent when the oxidation is greatest. M. Chaptal has however discovered, that the various buff, and the imitations of nankin colours, may be greatly improved by

* "Cet acide," says M. Chaptal, "est préféré au vinaigre pour tous les usages de la teinture et de l'impression sur toile: il porte avec lui une huile qui forme un excellent mordant pour les toiles de lin et de coton, et déjà il remplace l'acide acétique dans les teintures, où il sert à composer ce qu'on appelle le *bouillon noir*, ou le mordant pour les noirs, les violets, les pruneaux, les lilas, les nankins, etc. Les couleurs portées sur ce mordant sont plus nourries, plus vives, et beaucoup plus fixes, que celles que produit l'acétate ordinaire de fer." Chim. appliquée aux Arts, tom. iii. p. 169. He adds, in the next page, "Lorsqu'on veut employer aux usages de la teinture l'acide acétique provenant de la distillation, il est inutile, il seroit même préjudiciable à ses propriétés, de lui enlever l'huile qu'il tient en dissolution."

The pyroligneous acid is dark-coloured, and exhales an empyreumatic odour.

combining the oxide of iron with *alumine*, or the earth of alum; and for this purpose he first impregnates the cotton with the oxide of iron, by working it sufficiently and equally in a solution of that metal by the pyroligneous, or other vegetable acids, or, in default of these, in a solution of the sulphate of iron, marking three degrees on the areometre of Beaumé, and, after wringing it properly, *plunges* the cotton *immediately* into a solulution of potash marking two degrees, with which a saturated solution of alum has been just mixed, but so as *not* to precipitate the alumine. By this last mixture, the colour of the oxide of iron is considerably raised, and it also acquires an agreeable, smooth, even, and *soft* appearance like velvet, which could never be produced with the oxide of iron *unmixed;* it has moreover the advantage of preserving the fibres of cotton from injury by the solution of iron: after being thus immersed five or six hours, the cotton is to be properly wrung, washed, and dried; and by the last part of this operation, it will generally become deeper, from an accession of oxygene. M. Chaptal distinguishes the varieties of colour dyed in this way, by the names of "nankin, chamois, noisette, et rouillé." Ann. de Chim. tom. 26. p. 270.

The application of potash conjointly with an oxide of iron, *but without alum*, for dyeing the colours before mentioned, has been practised, particularly at Manchester, for almost half a century. But for this purpose a solution of iron by aquafortis was commonly employed, though injudiciously, as it certainly contributed more than any other, to hurt the fibres of the linen or cotton dyed therewith.* All these colours, though in

* In the Transactions of the Dublin Society, vol. i. part 1, may be found an account of "a process for dyeing a nankin colour," by Mr. Richard Brewer. The colour is produced by an oxide of iron;

other respects very durable, are liable to be spotted, and made black by being accidentally wetted with a little tea, or with the juices, or infusions of a great number of vegetable, and some animal matters, which are capable (as will be hereafter noticed) of producing an ink with iron.

For topical application by the pencil, or block, Haussman recommends Stahl's alkaline tincture of iron, made by dissolving that metal in aquafortis, and adding to it carbonate of potash *in excess*, sufficient to decompose and *re-dissolve* the nitrous oxide of iron; and afterwards thickening the solution with gum, &c. as usual. Commonly, *however*, a solution of iron by some of the vegetable acids (called iron liquor) is employed for this purpose, adding to it a portion of sulphate of iron, to increase its strength, when very full and deep stains are required.

Iron dissolved by muriatic acid, assumes a greenish colour, and the solution being applied to linen or cotton, the oxide adheres permanently; and, by an accession of oxygene, affords a *fine yellow stain*. A single washing will however so far affect the proportions on which this colour depends as to reduce it to the common ironmould colour.

Copper.

Only two oxides, or compounds of this metal with oxygene, are known to exist; one of these, *naturally* formed, is distinguished by the name of *ruby* copper ore. Its colour is a dark or brownish *red;* though the artificial imitations of it have, I believe, never risen much above an orange colour. This native oxide is

and the process consists of eight troublesome and expensive operations, which do not seem to be compensated by any adequate advantage.

supposed to contain about eleven per cent. of oxygene; but neither it, nor any artificial imitation of it, has yet, as I believe, been employed for a substantive colour in dyeing or calico printing. I, however, very recently and unexpectedly produced, and *fixed permanently* upon calico, a brownish *red* oxide of copper, very nearly resembling the ruby copper ore in colour. It has withstood repeated washings with soap, and six weeks exposure to the weather, without alteration; and may, I think, prove useful, by simple topical application, in calico printing; but in this instance, it was the result of a complicated mixture, made for another purpose, and I have not yet had time to simplify the process sufficiently. When I shall have done so, I intend to make it public. In appearance it resembles another very permanent colour, which I discovered twenty years ago. I mean the *red* prussiate of copper, to be mentioned hereafter.

The other oxide of copper is supposed to contain about twenty per cent. of oxygene; but it has never, I believe, been employed for dyeing or calico printing.

The *green* colour exhibited by most of the preparations of copper, commonly results from the absorption, or addition of carbonic acid, for which the oxides of copper have a marked affinity; it may be produced also by the admixture of muriatic and some other acids. There is however, I believe, none of the acid green solutions of copper or its oxides, which after being applied simply to cotton or linen will bear to be washed with soap, though their colours generally withstand the impressions of sun and air for a considerable time. But if liquid ammonia be saturated with copper, and thickened with gum, it may, by simple topical application, be fixed upon linen or cotton, where, by an evaporation of a part at least of the volatile alkali, and an absorption,

probably, of both oxygene and carbonic acid, its blue colour will be changed to a green resembling that of *verdigrise*, or rather that of the malachite, which will very sufficiently resist the impressions of sun and air, and bear a considerable number of washings with soap without being much weakened thereby. It may, therefore, be usefully employed in this way, especially upon *fine muslins*, by reason of the great delicacy of its colour, and the *facility* of its application. I have several times thought that an effect somewhat better had resulted, when, instead of dissolving the copper by ammonia, I combined the latter with a *nitrate* of that metal. Verdigrise dissolved by ammonia, also produces good effects used in this manner. A similar beautiful, though pale green, may be substantively dyed upon woollen cloth, by the sulphate of copper with a sufficient portion of carbonate of lime, to neutralize the acid. This colour will not indeed bear the action of soap, but it does not appear to suffer any considerable change or diminution, by the impressions of sun and air for a long time.

The oxides and solutions of copper are all susceptible of combination with most of the adjective colouring matters, and may be usefully employed as mordants or bases with some of them, which will be duly noticed hereafter.

Gold.

When this metal is dissolved in nitro-muriatic acid, the result, as Proust has observed, seems to be a pure and simple muriate of gold: and when beaten into leaves, and burnt by electricity, or calcined by the sun's rays, concentrated and reflected by a burning mirror, it affords a *purple* oxide: and this it also does when precipitated from aqua-regia by the muriate of tin. In this last opera-

tion, as well as in the former, the purple colour depends entirely upon the oxide of gold; that of tin, though combined with it, being colourless. This precipitate has been called the purple of Cassius, though improperly, because it was known to earlier chemists, particularly Neri, Glauber, and Kunkel. The supposed oxides, or precipitates of gold, obtained by mixing either of the alkalies, or lime or magnesia with a solution of gold, are yellow; but such precipitates appear (as Davy has observed) to be triple compounds. Having soaked muslin in a diluted solution of gold by aqua regia, for a single minute, I exposed it whilst wet to the direct rays of the sun in the month of September, and found, in less than a quarter of an hour, that the fine yellow colour which it had received from the muriate of gold, was become partially *violet*, excepting only a few round spots, to which I had previously applied a solution of crystals of soda thickened with gum; in these spots the alkali had neutralized the acid, and produced a colour resembling that of bright iron-mould, upon which the rays of the sun made no impression, or change; the violet colour, so produced, soon became general, excepting the spots last mentioned; and, by a further exposure to the sun's rays, this colour was gradually reddened, and converted to a sort of crimson purple, in consequence, as I presume, of a farther de-oxygenation of the metal, which, from this progressive change of colour, appears to be susceptible of different degrees of oxidizement. A similar change was produced, much more expeditiously, when I applied a recently-prepared muriate of tin to cotton, impregnated with a solution of gold in aqua-regia, and dried in the dark; an abstraction of oxygene, and a partial revival of the gold, having been almost instantaneously manifested, by the appearance of a violet colour, where the muriate of tin had

been applied, and in no other part. Count Rumford, also, (as is stated in the Phil. Trans. for 1798,) produced a purple colour by impregnating white silk, linen, and cotton, with a solution of gold, and exposing them to the direct rays of the sun, but he had previously separated a great part of the nitro-muriatic acid, employed to dissolve the gold, by evaporating the solution to dryness, and afterwards re-dissolving the oxide, or salt of gold, in water; a precaution which I did not employ. He found, (as I have done) that no change of colour took place in the dark; but here it must be observed, that he made no trial of the deoxygenating power of the muriate of tin, which, when employed by me, readily produced the violet colour without the aid of light.*

Antecedently, however, to count Rumford's experiments, Mrs. Fulhame (in an essay on combustion, published in 1794) had given an account of several ingenious attempts not only to fix the oxides of gold upon silk, but to revive the gold afterwards with its *metallic lustre*, principally by the application of hydrogene gas, and phosphuretted hydrogene, which in some degree produced the desired effect, though it was found impossible to make the revivification so generally equal, as to produce that uniformity of gilding, which could alone compensate the expense of it.

* More than half a century ago, Hellot had observed that characters traced on writing-paper with a diluted nitro-muriate of gold began, after a few hours exposure to the *air*, (he should have said *light*,) to manifest colour, and soon after became of a very dark violet—"violet foncé presque noir." But when shut up in a close box, he says, the writing did not become visible during several months. And he adds, that the like happened to characters written with a diluted nitrate of silver, though they became very visible in in the space of hour when exposed to the sun's rays. See Mém. de l'Acad. R. &c. 1737.

In consequence of Mrs. Fulhame's publication, count Rumford attempted a more complete revival of gold, by mixing with his aqueous solution of its salt (before mentioned) sulphuric ether, which soon attracted and united itself with the gold, swimming upon the surface and leaving the water colourless: and this mixture being afterwards exposed to the rays of the sun, the metal soon revived in the form of gold leaf.

Such a mixture of sulphuric ether and the salt of gold has lately been found *useful to gild the points of lancets*, and protect them from rust; and if the expense be not too great, I am persuaded that white silks might be premanently gilt with it, *in spots* or figures, for which a perfect equality in the metallic appearance of the gold would not be required.

That precipitate of gold by tin, which has been commonly called the purple of Cassius, was soon after its discovery combined with glass to imitate *Rubies*, which it did perfectly, at least in their appearance, though not in their hardness; and in later times, this precipitate has been generally employed as a finer sort of enamel for porcelain, &c. By varying the proportions of tin, or rather of its solution, the colours of this precipitate may be varied through all the intervening shades from violet to crimson; and the precipitate, with all its various colours, may be permanently fixed as a stain or dye upon silk, linen, or cotton, by applying to them, either the solution of tin first, and afterwards the solution of gold; or the solution of gold first, and afterwards that of the tin: it will be advantageous, however, to let the silk, &c. to which one solution has been applied, become dry before the second is superadded.

Lately Haussman has found means to produce a purple mixture of tin and gold, *without any precipitation*,

by dissolving the metals with a great *excess* of the acids; which excess retains the oxides, suspended in the water, notwithstanding their union, and such a partial deoxygenation of the gold, as is necessary to its violet colour.

In this purple liquor diluted, silk may, as he says, be made to receive the most durable colours, by *repeated immersions*, &c. which are, as I presume, necessary, by reason of the redundant acidity of the liquor. I do not, however, think that any benefit can result from thus applying the solutions of these metals *mixed*, and *at the same times*, rather than *separately;* for in the latter way two immersions will be sufficient: and it is to be feared that this purple from gold, notwithstanding its great beauty and durability, will prove too costly for any thing, but a partial application in spots and figures.

In my judgment the principal, if not sole use of the solution of tin, in producing this purple, is that of abstracting oxygene from the gold; an effect which may be produced by other means. I have repeatedly found, that when a solution of gold in aqua-regia was applied to, and suffered to remain upon my fingers, they receive a purple stain which nothing could remove, but an abrasion or wearing off of the skin; and I have produced a similar effect from a solution of gold applied to silk, cotton, and linen, previously impregnated with matters suited (in like manner) to abstract oxygene; such as animal glue, linseed oil, caustic alkalies, yolks and whites of eggs beat up with sugar, or with orpiment, alkaline sulphurets, &c. &c.; and, cæteris paribus, I have found that the more the oxide of gold was deprived of oxygene, the more its colour approached to the crimson.

Silver.

The colours to be obtained *substantively* from the metals, excepting those of iron and copper, chiefly depend upon a partial revival of the metal; which revival cannot take place, without its abstraction or separation from the acid by which it has been dissolved; and to promote this abstraction, it is convenient and sometimes necessary to impregnate the linen or cotton intended to be dyed or stained, with some of the animal, alkaline, and deoxygenating substances just mentioned, as contributing to precipitate and partly revive the oxide of gold.

This observation is particularly applicable to the oxide of silver, which is properly of an olive-brown colour, but is rendered almost black by being deprived of a part of its oxygene, and thereby in some degree restored to its metallic form. The powerful efficiency of the sun's rays in the deoxygenation of silver has been already noticed at p. 40.

Leuwenhoek mentions (Philosoph. Transactions, vol. xxiv.), that by touching nitrate of silver, his fingers were stained black; and that, finding it impossible otherwise to remove the stain, he cut off and burnt the skin, and then examining it by a microscope, he found the silver revived in a multitude of little globules.—" I " have lying on my desk (continues he), a linen hand-" kerchief, which was stained with aqua-fortis, impreg-" nated with silver, with a large black spot about as " large as a shilling;" and he adds, that having ineffectually tried to discharge the colour by six washings, and by laying the handkerchief out to bleach, he cut out the stained part, burnt it to coal, and viewing it by a microscope, saw thousands of fine silver globules therein. The effect here mentioned to have been produced upon the

skin, accords with that which solutions of silver are known to produce in blackening hair, and other animal substances; but in reading this account, I thought it extraordinary that clean linen, impregnated with no animal, inflammable, or alkaline matter, should so far deprive nitrate of silver of its acid, as to produce the effect described; and I repeated the experiment several times without success. At length, however, I took a silver tea-spoon, which had stood half filled with aqua-fortis for several weeks, and which on the hollow inside was become almost black by it, and by the oxygene of atmosphere which it had attracted, and having poured out the more fluid part of the solution, I rubbed a bit of cambric against the wet oxidated hollow surface, and hanging it up for a few days in the open air, on the south side of a wall, I found the cambric permanently stained of a very dark violet colour. A fine piece of cotton, however, by the same means received only a very slight discoloration. But cotton, when impregnated with soda and the acidulous arseniate of potash, acquired a strong durable slate colour by being touched with diluted nitrate of silver; a drab colour by the same means, when impregnated with soda and sugar; a dark olive brown, with sulphuret of potash (liver of sulphur), and spirit of wine; and the like with soda, liver of sulphur, and sugar; and being impregnated with white of egg, beat up in water with sugar, the cotton received from the nitrate of silver a very strong brownish black; and when caustic vegetable alkali was added, it became a little blacker. The yolk, instead of the white of egg, produced nearly the same effect. All these colours were often washed, and exposed for a long time to the weather, without being changed.*

* During the last twenty years an ink has been sold, and extensively used for marking linen, &c. which it does *permanently*, by

Mercury.

The oxides of mercury very easily give up their oxygene, and are, therefore, readily precipitated by the means before mentioned, upon vegetable as well as animal substances, affording generally either black or dark colours, though of but little permanency, because the residue of their oxygene soon separates, and the mercury recovers its fluid metallic form. Nitrate of mercury applied to cotton, which had been impregnated with soda, produced at first a yellow, which soon changed to an olive, and being washed with soap, to a full black colour; but after a few days exposure in the open air, it almost entirely disappeared. On cotton, impregnated with soda and sulphuret of potash, it immediately produced a black, which, by washing and exposure in open air, changed in about ten days to an olive, and soon after disappeared. On cotton, impregnated with sulphuret of

means similar to those just mentioned. To prepare this ink, a white precipitate of pure silver is procured, by dissolving that metal in nitric acid, and afterwards separating it from its *alloy*, by suspending in the solution, a thin slip of copper, which by its greater affinity for the acid, throws down the silver in the form of a white powder, which powder being afterwards mixed with an aqueous solution of white glue and gum arabic, forms the ink. But to render this preparation effectual, the linen, &c. to which it is applied by the *pen*, must have previously received an impregnation like some of those which I have recently described, though they are, in *this*, rendered less necessary, because the precipitate of silver retains but a small proportion of acid, as is manifested by its want of solubility in water, which makes it expedient to shake the mixture as often as it is used. The impregnation most commonly employed seems to consist of isinglass, and white animal glue dissolved in spirit of wine, which being applied to the part intended to be marked, is suffered to dry; after which it is fit to be written upon with what is called the ink. Additional means havesometimes been employed to increase the blackness of the latter, but their effect will not last.

potash and spirit of wine, it also produced a black, which disappeared like the former; and with caustic vegetable alkali it produced nearly the same effect. With orpiment, dissolved by potash, it produced a very *deep black*, which stood two or three weeks exposure to the weather; after which the mercury began to revive, in very small globules, and the colour to disappear in spots.*

Platina.

This metal was first discovered at Choco and Santa Fé, in South America, and was not known to exist naturally in any other place, until Vauquelin lately detected it among the grey silver ores of Guadalcanal in Estremadura; and more recently Dr. Wollaston has examined and described a small specimen, which had been found in Brazil, intermixed with palladium. See Phil. Trans. 1809.

Proust says, the result of a solution of platina in the nitro-muriatic acid, is (like that of gold so dissolved) a pure and simple *muriate*.

The oxide of platina, at the maximum of oxygenation, is of a yellowish brown colour; but when heated and deprived of about one half of this portion of oxygene, it becomes green.

* I have now before me some *very black* writing upon calico, which states *itself* to have been written with a solution of nitrate of quicksilver, upon calico impregnated by a mixture of soda, liver of sulphur, and sugar, in water: seventeen years have elapsed since this writing was performed, and there is no appearance of that *revivification* of the mercury, which I had experienced when it was used upon calico with impregnations differing but little from that last mentioned.

Professor Gmelin of Gottingen, in his publication, " de tingendo per nitri acidum," &c. mentions the staining of silk with a *copper* colour by mercury, dissolved in nitric acid.

Having immersed a bit of fine calico in a diluted solution of platina, by nitro-muriatic acid, it acquired a yellowish orange colour, and this being afterwards dried, I dipped it into a diluted solution of tin by muriatic acid, to see what effect would result from an abstraction of oxygene (which I expected) by the latter; and to my surprise, I saw the colour instantaneously changed to that of *arterial* blood. This calico being afterwards dried and washed with soap, its beautiful red was thereby made to incline very much to a bright full orange colour, which did not change by subsequent washings, and seems to be permanently fixed. Though somewhat costly, it probably may be susceptible of some useful application to fine muslins in calico printing. In the production of this colour, the solution of tin seems to act as it does in producing a *purple* with gold.

The solution of platina (without that of tin) being applied to calico, produced a yellow colour, which, when washed, seemed to be permanent, though it was afterwards raised to a bright high orange, by applying to it the solution of tin last mentioned.

The same solution of platina, being applied to calico, which had been soaked in a prussiate of lime, produced a brown colour, which, by washing with soap, became a dark violet, which seems to be permanently fixed. Similar effects were afterwards produced by the prussiate of potash.

Other pieces of calico impregnated severally with sulphuret of potash; with soda, and the acidulous arseniate of potash; with orpiment dissolved by liquid potash; with liver of sulphur and alcohol; and with lintseed oil; and afterwards soaked in the before-mentioned solution of platina diluted, acquired different shades of purple, olive, and brown colours, which, when washed with soap, appeared to be permanently fixed.

Manganese.

The great variety and mutability of colours afforded to water, in different proportions, and of different temperatures, by manganese in combination with potash, was long since observed by Glauber, as is noticed at page 13 of this volume. Whether the alkaline solutions of this oxide are capable of being usefully employed to dye substantive colours, I am unable to decide; my experiments therewith having been too few. I have found, however, that a considerable variety of lasting brown, or dark-coloured stains, may be produced upon bits of linen and cotton, which have previously and severally received the different impregnations before mentioned, by applying to them a diluted sulphate of manganese; and without any such impregnation, if the latter be applied to linens or cottons, and they be afterwards dipped into a weak solution of potash or soda, a yellowish brown colour will be produced; and this, by attracting oxygene, will gradually change to a *dark*, and *very durable brown*. But if to this otherwise lasting dark colour, a solution of tin by muriatic acid be applied, it will restore the former yellowish brown, by causing an abstraction of oxygene from the manganese; though the latter by its affinity for oxygene will afterwards *repair this loss*, and by doing so will restore the former dark brown colour.

Cobalt.

The nitrate of cobalt may be decomposed by liquid potash, and it will then afford a blue precipitate, which if secluded from atmospheric air will become *violet*, and afterwards *red*.

Nitrate of cobalt applied to cotton, impregnated with

soda, with soda and acidulous arseniate of potash, and with caustic vegetable alkali, produced lively pink and rose colours, which stood washing and exposure to weather for a considerable time.

The oxide of cobalt, dissolved by muriatic acid, and applied to cotton impregnated with soda, when held to the fire, exhibited the most beautiful green, which, as the cotton cooled, changed to an apple-green; then passed through all the shades of yellow, and became a kind of pale buff colour, which the oxide retained after the cotton had been washed with soap; but then on being heated, it was found to have lost the property of becoming green, though on dipping it into a diluted muriatic acid, it immediately regained and exhibited the same property. These effects are connected with those which similar solutions of cobalt produce as sympathetic inks; though I confess myself dissatisfied with all the explanations hitherto given of them. The presence of muriatic acid is essential to their existence, the nitrate of cobalt producing no such phenomenon;* nor did I find that the presence or absence of light had any effect in retarding or promoting any of the changes of colour here mentioned.

* Having lately soaked a bit of calico in a diluted nitrate of cobalt, it exhibited a pale rose colour, when dried. To the calico so coloured I applied a solution of tin by muriatic acid, in *spots*, and afterwards holding the calico to the fire, I soon observed that these spots were all of a most *beautiful blueish green*, whilst every other part retained its rose colour. By removing the calico from the fire, and letting it cool, the spots again became rose-coloured. Having afterwards rinced the calico in water, the parts which had been spotted lost the power of becoming green when *heated;* but by wetting them with muriatic acid, they regained this power, a proof that this acid, and not the tin dissolved by it, had, in the first instance, enabled the fire to produce the blueish green colour.

Nickel.

If this metal be dissolved by nitric acid, the solution may be decomposed by potash, and a grass-green hydrated oxide will be thereby obtained. By impregnating calico with a mixture of soda and sugar, and immersing it in a diluted solution of nickel by the nitric acid, a similar green was produced on the calico; but it did not prove sufficiently durable, to be employed in dyeing or calico-printing.

Molybdena, titanium, palladium, and osmium, afford coloured oxides of considerable beauty and variety, which probably might be applied and fixed upon silk, linen, and cotton, were not these metals too scarce and costly, especially the latter, for this use.

Berthollet has mentioned, (Ann. de Chimie, tom. i.) that the simple mixture of an oxide of lead with lime, will blacken wool, hair, &c.; and that some persons have used it to render grey hairs black. Wishing to ascertain its effect in dyeing, I boiled flannel in lime-water with litharge, which produced a tolerable black upon the flannel; and this black was not diminished by washing the flannel with soap, and exposing it for the usual time to the weather: strong acids, however, dissolved the lead, and discharged the colour: and the lime was found to have weakened the texture of the flannel considerably, and more especially when orpiment was *added;* an effect similar to that which it produces in those depilatory compositions which were brought to Europe from Turkey.

Perhaps my readers may think, that many of the preceding experiments are such as the great Bacon (Lord Verulam) has termed "*experiments of light rather than of fruit* " But such experiments are not to be neglected in a work which professes to treat of the *Philosophy* of

Colours, though they should not be susceptible of any considerable *practical* advantage, or application.

With this observation, I finish my account of substantive colouring matters. They claimed my earliest notice, because their properties and modes of application are generally the most simple and intelligible; and because some of them, particularly the oxides of metals, may also be made to serve as the bases of adjective colours, which will become the subject of our next inquiries.

END OF PART I.

EXPERIMENTAL RESEARCHES

CONCERNING THE

PHILOSOPHY

OF

PERMANENT COLOURS.

PART II.

CHAPTER I.

Of Adjective Colours generally, and their bases; with an illustration of their effects upon each other, as exemplified by Oriental and European calico-printing.

"Les faits sont de tous les temps, ils sont immuables, comme la nature dont ils sont "le langage; mais les conséquences doivent varier selon l'état des connoissances "acquises." CHAPTAL, *Elémens de Chimie.*

ADJECTIVE colouring matters are generally soluble, in a great degree at least, by water; though some of them derive their solubility from an intermixture of what has been called *extractive* matter; which being separated in the dyeing process, after the adjective colour has been applied to the dyed substance, their union becomes thereby more intimate and permanent. But in other respects, adjective colours owe their durability, as well as their lustre, to the interposition of some earthy or metallic basis; which, having a considerable attraction, both for the colouring matter and the stuff to be dyed, serves as a bond of union between them, and obviates that disposition to suffer decomposition and decay, which naturally belongs to such colouring

matters when *uncombined.* These earthy and metallic bases, having been commonly employed in a state of solution or combination with acids, were from that circumstance denominated *mordants* (biters or corroders) by the French, who, indeed, began to employ the term long before any thing like a true theory of dyeing had been conceived; whilst even alum was supposed to act by its sulphuric acid, and not by the pure clay upon which its usefulness depends, and whilst in truth all the other matters called mordants were supposed to be useful only by their solvent or corroding powers; and the term, having been thus employed, has been since adopted in other countries. The ingenious Mr. Henry, of Manchester, has, however, lately objected to it, with great reason,* and proposed in its stead to employ the term *basis*, which seems defective only, inasmuch as it does not express the particular *affinity*, or *power of attraction*, manifestly subsisting between these earthy and metallic substances, and the several adjective colouring matters, as well as between the former and the fibres of wool, silk, cotton, &c. I confess, however, that no other more suitable term has occurred to me; and being unwilling to propose new terms, without some cogent reason, I shall sometimes employ that of mordant as well as that of basis; though not indiscriminately in all cases; since I shall generally use the former to signify earthy and metallic substances when *actually dissolved* by some acid, alkaline, or other solvent, and when of course they will commonly prove more or less corroding or biting, according to the original meaning of the term. But the denomination of basis will be most frequently used to designate the same earthy and metallic substances, dis-

* See his "Considerations relative to the nature of Wool, Silk, and Cotton, as objects of the Art of Dyeing, &c." in the third vol. of the Memoirs of the Manchester Society.

tinctly and separately from any acid or other solvent, when actually fixed in the pores or fibres of wool, silk, &c. or when it is not intended to notice any property in them, which may more immediately result from their combinations with any particular menstruum. M. Berthollet, indeed, gives the term mordant a much more extensive signification, as meaning all the different chemical agents capable of serving as *intermedia* between the several colouring particles and the stuffs so dyed with them, either for the purpose of assisting their union, or of modifying it.* This last effect (of modification) may, however, be produced by a variety of matters besides those which are of the earthy or metallic kinds, and indeed by every thing capable, not of fixing, but of merely varying, the shades of adjective colouring matters. These, therefore, I think it more proper to designate, not as mordants or bases, but as *alterants*,† whose use and application may in this respect be extended to substantive as well as to adjective colours.

The bases pre-eminently useful with adjective colours, are the earth of alum, and the oxides of tin and iron, held or applied in solution by an acid menstruum: and, excepting the process for dyeing black upon woollens and silks, it is generally deemed most advantageous to combine these bases first, and separately, with the stuffs to be dyed, superadding the colouring matters afterwards; because the affinity or attraction of the basis, is commonly greater for the latter, than for either wool,

* "L'on donne le nom de mordant aux substances qui servent d'intermèdes entre les parties colorantes et les étoffes que l'on teint, soit pour faciliter leur combinaison, soit pour la modifier." *Elémens de l'Art de la Teinture*, tom. i. p. 26, of the first edition.

† M. Berthollet, in his *last* edition, tom. i. p. 71, has adopted the term of *alterants*, and employed it in the way which I had suggested, as above, in my first publication.

silk, cotton, or linen; particularly that of the earth of alum, which, when applied subsequently to, and upon the colouring matter, forms with it a kind of lake, by which their respective affinities are in a great degree exerted towards, and saturated by each other; and the size of their particles being thereby increased, they do not penetrate copiously into, nor combine intimately with the fibres of wool, silk, &c.; but remain in a great degree suspended in the dyeing liquor, or precipitated to the bottom of it. But by combining the basis *previously*, and separately, with the stuff to be dyed, and afterwards applying the colouring matter, this last, when so applied, is powerfully attracted by the conjoined affinities of the former, so that the dyeing liquor may be completely exhausted, and made colourless thereby.

It must, however, be noticed in regard to *wool*, that by reason of its *greater* attraction for metallic oxides, they may, without any considerable disadvantage, be applied to it, in conjunction with adjective colouring matters, as will be mentioned in regard to the dyeing of *scarlet* and some other colours. It ought also to be observed, that when colours are dyed upon wool, silk, &c. by the aid of an aluminous or metallic basis, the colour is applied, or dyed more immediately upon the latter, than upon the wool or silk, &c. as will be made evident hereafter. The durability therefore of an adjective colour must depend, not only on the natural stability of the colouring matter, but also upon the energy of its affinities, both for the stuff which is dyed, and for the basis or intermedium upon which it is immediately applied, and which, by its own peculiar attractions, binds them to each other.

The true nature and uses of mordants or bases, for the purposes under consideration, can, I believe, in no way be so distinctly manifested, or so clearly illustrated,

as by their effects in what I shall call *topical* dyeing, or that species of it by which different colours are communicated to particular spots or figures on the same piece of cotton or linen, according to the several bases previously applied thereto, and which principally constitutes that truly wonderful art, the art of calico-printing. I shall, therefore, in this place, bring under my reader's notice some of the more important operations of that art, reverting at the same time, as far as we can, towards its remote origin, in order to see how, and by what means, it has attained its most important improvements.

Pliny describes the Egyptians as practising a species of topical dyeing, or calico-printing, which, as far as can be discovered from his general terms, appears to have been similar to that which, many ages after, was found to exist in Hindostan and other parts of India, and was from thence introduced into this and other countries of Europe. He says, the Egyptians began by painting or drawing on white cloths, (doubtless linen or cotton,) with certain drugs, which in themselves possessed no colour, but had the property of attracting or absorbing colouring matters. After which, these cloths were immersed in a heated dyeing liquor; and though they were colourless before, and though this dyeing liquor was of one uniform colour, yet when taken out of it soon after, they were found to be wonderfully tinged of different colours, according to the different natures of the several drugs which had been applied to their different parts; that these colours, so wonderfully produced from a tincture of only one colour, could not be afterwards discharged by washing; and he considers it as admirable, that the dyeing liquor, which, if cloths of different colours had been put into it, would have *confounded* them

all, should thus produce and permanently fix several colours, being itself only of one.*

Whether the Egyptians borrowed this wonderful art from the Hindoos and other inhabitants of India, or whether the latter borrowed it from the Egyptians, is a question which probably may be answered without much difficulty, if we consider the many reasons which exist for believing that this art has been practised over a great part of India during a long succession of ages; that not only the art itself subsisted there, but that the colouring and other materials for exercising it, were the natural and *peculiar* productions of that country, rather than of Egypt; that the Indians were highly civilized at least twenty-two centuries ago, during which space of time their manners, sanctified (if I may so express myself) by being connected to their religion, suffered little, perhaps no change; that their trades were carefully perpetuated in particular families; and also that among these their manufactures were undoubtedly of very great antiquity, whilst obvious ways, by which they might have been easily extended to Egypt, and other countries, undoubtedly existed long before the time when Pliny wrote.

Major Rennell observes, that "a passion for Indian "manufactures and products has actuated the people "of every age, in lower Asia, as well as in the civilized

* "Pingunt et vestes in Ægypto inter pauca mirabili genere, "candida vela postequam attrivere illinentes non coloribus, sed co-"lorem sorbentibus medicamentis: hoc cum fecere, non apparet in "velis: sed in cortinam pigmenti ferventis mersa, post momentum "extrahuntur picta. Mirumque, cum sit unus in cortina color, ex "illo alius atque alius fit in veste, accipientis medicamenti qualitate "mutatus: nec postea ablui potest. Ita cortina non dubiâ confusura "colores si pictos acciperet, digeret eos ex uno, pingitque dum co-"quit." PLINII, l. xxxv. cap. ii.

"parts of Europe: the delicate and unrivalled, as well "as the coarser and more useful fabrics of cotton of "that country, particularly suiting the inhabitants of the "temperate regions along the Mediterranean and Eux-"ine seas. To this trade (continues he) the Persian and "Arabian Gulfs opened an easy passage; the latter par-"ticularly, as the land carriage between the Red Sea "and the Nile, and between the Red Sea and the Me-"diterranean, took up only a few days. It is highly pro-"bable, and *tradition in India* warrants the belief of it, "that there was from time immemorial an intercourse "between Egypt and Hindostan, at least the maritime "part of it; similarity of customs in many instances, as "related of the ancient Egyptians by Herodotus, (and "which can hardly be referred to physical causes,) ex-"isting in the two countries."—"It would appear, that "under the Ptolemies the Egyptians extended their "navigation to the extreme point of the Indian Conti-"nent, and even sailed up the Ganges to Palibothra." See Memoir and Map of Hindostan, &c. 4to. by James Rennell, F.R.S.

The best accounts of the practice of *calico-printing** in the East Indies, were given in certain letters, written by Father *Cœurdoux*, a missionary at Pondicherry, (published in the 26th volume of "Recueil des Let-"tres Edifiantes, &c.") with the supplemental remarks and corrections of Mons. Poivre; and in a manuscript account procured from thence by Mons. Du Fay, and communicated to the Royal Academy of Sciences at Paris, by the Abbé Mazeas;† and also in the report

* I here continue to use this term, though in truth none of the mordants or colouring matters, employed to stain the calicoes of India, were applied by engraved blocks or plates as in Europe, but by the pencil.

† "Recherches sur la cause physique de l'adhérence de la cou-

made in 1735 by M. Beaulieu, (then a captain in the French navy), of the operations which, at the request of Du Fay, he caused to be performed under his *own inspection*, at Pondicherry, and by which a piece of chintz was completely printed or stained of various colours, as described in a little publication, entitled, "Traité sur les toiles peintes, dans lequel on voit la manière dont on les fabrique aux Indes," &ç. From these several accounts, as well as from some valuable private information which I have been able to procure, the following concise statement has been composed, of the principal operations by which the chintz calicoes of India received the colours for which they were highly celebrated before the art of calico-printing had been introduced and simplified in Europe. The cotton cloths, when brought from the weaver, partly bleached, were worn next to the skin, by the dyer and his family, during the space of eight or ten days; after which they underwent several macerations in water with goat's or sheep's dung, accompanied by frequent intermediate beatings, washings, and dryings (by exposure to the sun.) Afterwards they were soaked for some time in a mixture of the astringent external part of the fruit of the yellow myrobalan tree,* (separated from the nut and powdered) with

leur rouge aux toiles peintes qui nous viennent des côtes de Malabar et de Coromandel:" par M. l'Abbé Mazeas, correspondant de l'Académie, &c. Mém. des Sçavans Etrangers, tom. iv.

* The fruits of several trees not yet accurately distinguished, or ascertained, have been called myrobalans: that species which is here meant, belongs to the genus *terminalia*, to which the trivial or specific name of chebula, or that of citrina has been applied. See Retzius's Observations. It is the *badamier* of the French, and *her* of the Hindoos. The ripe fruit is yellow, and pear-shaped, with five longitudinal angles; and, when dried, appears wrinkled. It consists of a white pentangular nut, covered by a mucilaginous and highly astringent substance, nearly two lines in thickness; and

buffaloes' milk; and being thoroughly penetrated and impregnated therewith, they were taken out, and the liquor being well squeezed from them, they were again dried by exposure to sun-shine, and afterwards, by pressure and friction, with wooden rollers, they were made smooth enough to be drawn upon by the pencil, with the different mordants (according to patterns previously traced out and marked by powdered charcoal). The first of these mordants was an iron liquor (acetite of iron), similar to that since employed by the calico-printers of Europe, excepting only that, instead of vinegar or alegar, the iron was dissolved by a mixture of sour palm wine, and of water in which rice had been boiled.* This liquor was applied to the figures or spots

within the nut is a small white oily kernel. The nuts are separated from the astringent substance which covers them, by bruising the fruit under a wooden roller or cylinder, it being the external astringent substance only, or an infusion or decoction thereof, which is generally employed throughout India for dyeing or calico-printing, and which, by very decisive experiments, to be mentioned hereafter, I have found to be capable of answering all the purposes of *galls*. Indeed the leaves of this tree afford a sort of flattish yellow irregular *galls*, produced by the punctures of a particular species of insect; which galls are collected and sold in all the bazars or markets: they are called *aldecay* by the Telingas, or Hindoos of the Circars, and cadacay or caducay by the Tamuls: and they produce with iron a strong durable black dye, and ink; and with alum a very full, though dark brownish yellow. If these galls were bruised so as to occupy less space than they otherwise must, by reason of the cavities contained within them, they might be advantageously imported into this country, as might also the external astringent substance of the fruit of the terminalia chebula separated from its *useless* nut. By some persons the unripe fruit is preferred, as having most acerbity or astringency.

* In the letters of Father Cœurdoux, the water in which rice had been boiled, and which was converted to a sort of vinegar, is termed canje, and the vinegar from palm wine is named callou. In these, bits of old iron and the vitrified matter of a smith's forge

intended to be made black, by a combination of the oxide of iron, with the colouring matter of the myrobalans.

By this method of producing black stains, the colouring matter is applied previously to the metallic basis, contrary to the practice in regard to most other colours. But in this the strong attraction of oxide of iron for the fibres of cotton, as already mentioned, obviates the evil which would result from a similar application, where *other* mordants were intended to follow.

When the black figures or stains have been thus produced, the blue are next to be given, and as a preparation for this, it is thought necessary to remove the astringent and oily matters which the calico had imbibed in every part, by being soaked in the mixture of buffaloes' milk, and powder of myrobalans; and for this purpose it is macerated during twenty-four hours in the dung of goats, or sheep, diluted with water, then rinced thoroughly and repeatedly in clean water, and dried in the sun: after which the figures intended to be made blue, are marked by outlines traced with powdered charcoal mixed with a solution of gum; and this being done, every other part not intended to be made blue, is covered with melted wax, to protect it from the indigo: and then the calico is sent to the blue dyer, and by him immersed in the *cold* indigo vat described at p. 151; and being sufficiently dyed, the wax is afterwards removed by covering the calico with boiling water, which melts the wax, and this last rising to the top, is separated when the water cools. But as the wax cannot in this

powdered, were macerated and exposed to the sun, until a sufficient solution had been effected. According to Dr. Roxburgh, the Telingas gives the name of *cassim* to their solution of iron, made by palmira toddy, or the juice of Borassus flabelliformis, (a species of palm) turned to vinegar.

way be completely removed, the calico is again soaked in a mixture of goat's or sheep's dung and water, rinced, dried in the sun, beat and afterwards soaked and boiled in water with *olla*, or washermen's earth, (which seems to be a natural mixture of soda and chalk) then macerated in water with cow-dung, and again well rinced, dried in the sun, and beat. After all these operations, the calico is again to be impregnated with the same oily and astringent matters which were removed to make way for the indigo blue, by soaking it again in the mixture of buffaloes' milk and myrobalan powder, drying and making it smooth, as before. And this being done, the calico will be in a fit condition to receive the aluminous mordant, upon which the red is afterwards to be dyed; which mordant is to be applied according to figures marked out with powdered charcoal: and when purple and violet figures are to be produced, they are to be in like manner designated; and for these, a mixture of the solution of iron, with the aluminous mordant, in suitable proportions, is to be applied; whilst for the figures intended to be *red*, the aluminous mordant *alone* is employed as a basis. These mordants are commonly applied by children, with the pencil, or with pointed wooden sticks.

To prepare this aluminous mordant, two ounces of alum were dissolved in two quarts of water, taken from certain pits, which water Father Cœurdoux has called "apre," probably because it held in solution a little soda, which there abounds in many places. To colour this solution, so that the strokes of the pencil in applying it might be visible, a little sappan or sampfan wood (cœsalpinia sappan of Linn.) in powder, was steeped in the solution, which being afterwards strained, was applied as before mentioned; after which the cotton so penciled, was exposed to the hottest sun-shine, in order

that the parts to which the mordants had been applied, might be dried as much as possible; and then the cottons were thoroughly soaked in large pits of water, to cleanse them from the loose superfluous parts of the different mordants, as well as from the buffaloes' milk, &c.; and this being done, they were slowly dyed in water moderately heated, with certain roots answering nearly in their effects to those of madder. Of these there are several sorts used for dyeing red in different parts of India, which will be more particularly noticed hereafter; that pointed out by the accounts in question, and most commonly employed, is called on the coasts of Coromandel and Malabar by the names of chay, chaia, chayaver, chailliver, and raye de chaye.* And after being dyed, the cottons underwent three different washings with goats' dung, soap, &c. and were then bleached by being exposed to the sun, and watered occasionally, to remove the stain on the parts intended to be left white.

It appears, that in this operation the buffaloes' milk, and more especially the astringent juice of the myrobalans, produced very beneficial and important effects, by their attraction for the aluminous earth, which contributed greatly to decompose or separate it from the

* This root was supposed, by M. M. Poivre, Hellot, and others, to be a species of *galium* or lady's bed-straw; afterwards, however, M. Duhamel de Monceau thought there was sufficient reason to consider it as the Hedyotis herbacea, Linn.: lately, however, Dr. Roxburgh has ascertained it to be a species of *oldenlandia*, to which he has annexed the specific name of umbellata; (see Plants of Coromandel, vol. i. p. 2, t. 3.) This indeed belongs to the same class and *order* as the galium and hedyotis (i. e. to the tetrand. monog. Linn.); and is called tsherivello by the Telingas; ché, saya-ver, and imbourel, by the Tamuls. Since my former publication on this subject, I have made numerous experiments with this root, of which an account will be given hereafter.

sulphuric acid, and consequently to fix it more firmly in the cotton; and being so fixed, it was enabled more strongly to attract and retain the colouring matter of the chay root when in the dyeing vessel, and thereby to produce a more permanent red colour in the different spots, figures, or designs, where the alum liquor had been applied.*

The astringent or colouring matter of the myrobalans also contributed essentially to produce the purple and violet stains, upon the parts or figures to which, for that purpose, a mixture of iron liquor and of the aluminous mordant had been applied, as lately mentioned; the chay root *not* having (as my experiments prove) the property, like madder, of producing those colours with iron.

After these operations, a *yellow* composition was applied by the pencil, &c. to the parts which had been preserved white; and when a green was wanted, to other parts which, with a view to that colour, had been dyed blue. This *yellow* composition was made by dissolving powdered alum in a decoction of the powdered galls of the myrobalan tree, called *aldecay* by the Telingas, &c. as just mentioned. In making this decoction, powdered turmeric and dried pomegranate rinds were sometimes put into the water, with the aldecay. But the yellow

* When a solution of alum is applied to calico which has received no impregnation, it will not be sensibly decomposed; but on the contrary, a great part of it will again crystallize, so soon as the water which held it in solution has evaporated; and none but very feeble colours can be raised upon such a basis. But when calico has been impregnated by such astringent and animal matters as are obtained from myrobalans and buffaloes' milk, the alum will not only be decomposed, but the alumine will combine with the astringent and oily matters so obtained, and a basis will be laid for a colour almost as durable as the Turkey red.

or green resulting from this application, will only endure a few washings, before it becomes almost obliterated. Father Cœurdoux pretends, indeed, that this defect may in a great degree be obviated by mixing with the yellow in question, some of the astringent juice of the root of the plantain (*musa*); but if this had been true, such mixture would doubtless have been employed, and in that case the yellow of the Indian chintz would not have proved so defective, as it is known to have been at all times.

In this composition we have an adjective colour directly combined, and topically applied with its basis, instead of being applied separately, as is most usual. Such compositions (which will be frequently mentioned hereafter) assume the form of a substantive colour, without being such in reality; and as it may be useful to distinguish them by an appropriated term, I beg leave to call them *pro-substantive topical colours*, and to apply that designation wherever an adjective colour, and its basis or mordant, are thus mixed and applied together *topically*, either by the pencil or the block.

The art of calico-printing, since its introduction to Europe, has been divested of many tedious operations and manipulations, which indeed would have proved insupportably expensive here, on account of the higher price of labour, and of almost every thing necessary to human subsistence.* But the greatest European improvement in this art, respects the aluminous mordant, and depends on the employment of sugar of lead (acetite of lead), or the oxide of that metal dissolved by

* Berthollet, tom i. p. 8, of his last edition, has delivered a similar opinion, and he adds in a note, "Cette opinion est confirmée par les détails *plus exacts* que l'on trouve dans Bancroft *Of Permanent Colours*."—He considers the art of dyeing in India as being now nearly in the state in which it was at the time of Alexander's invasion.

distilled vinegar, and crystallized; which within the memory of man has been gradually brought into use, without any theory, or even suspicion of its true effect, or of the way in which it has proved so highly useful. This improved aluminous mordant is now generally made by dissolving three pounds of alum in a gallon of hot water; then adding one pound, or in some particular cases one pound and a half, of the acetate or sugar of lead, stirring the mixture well during two or three days, and afterwards adding to it about two ounces of potash, and as many of clean powdered chalk (carbonate of lime). In this mixture, both the alum and the sugar of lead are decomposed by a double elective attraction, which produces two new compounds, according to Mr. Henry and M. Berthollet, because the oxide of lead having a stronger attraction for the sulphuric acid than for that of the vinegar, combines with the former, and, forming an insoluble salt, subsides to the bottom of the liquor, whilst the earth of alum, thus left in a very divided state, unites to, and is dissolved by the acetic acid, previously separated from the lead, and remaining in the liquor, which thereby becomes a diluted acetate of alumine; the potash or chalk only serving to neutralize the excess of sulphuric acid, which is always contained in alum, and which would in some degree hinder the alumine from being deposited and fixed in the fibres of linen and cotton. But the decomposition here described takes place only *in part*, because one pound of sugar of lead, or even one and a half, (the greatest quantity any where proposed,) is not sufficient to decompose three pounds of alum. On the contrary, I have found that alum cannot be completely decomposed, without nearly its weight of sugar of lead:* and

* Having added a pound of sugar of lead to a pound of alum dissolved in hot water, I found that though the alum was decomposed

where less has been used, I have always been able, by evaporation, to detect a quantity of it in the aluminous mordant. I shall have occasion hereafter to revert to this subject, and shall therefore content myself at present with remarking, that the printer's aluminous mordant is not, in fact, a mere solution of the alumine, or earth of alum, by the acid of vinegar, as those eminent chemists Mr. Henry and M. Berthollet have supposed; but that even with the greatest proportion of sugar of lead ever employed by the calico printers, it contains a considerable portion of alum in its original state; I mean that in which the argillaceous earth or alumine is combined with sulphuric acid. But, notwithstanding this circumstance, I shall generally consider this preparation as being in reality, what it is not strictly, an acetate of alumine; and shall commonly distinguish it either by that name, or by that of the printer's aluminous mordant.

The mixture or mordant in question being thus made, and the clear liquor decanted from the sediment, it is

and a pure acetate of alumine produced, yet the acetic acid, which had dissolved the lead, was not sufficient to re-dissolve the whole of the alumine, a part of it having subsided with the sulphate of lead; it was, however, soon dissolved by adding vinegar to it; and this solution, when made with strong vinegar, proved as efficacious as the pure acetate of alumine in fixing the colours of madder, &c.

Gay Lussac has observed that an acetate of alumine, which when cold is perfectly *transparent*, becomes turbid and deposits a part of its alumine when heated, and that if left to cool again, the aluminous sediment will be re-dissolved, and the liquor recover its former transparency: an effect which he thinks analogous to the coagulation of albuminous matter by heat, of which he has given an explanation at p. 197, of the 74th volume of the Annales de Chimie. The fact, however it may be explained, enables us to understand (what experience had in some degree previously suggested) why the aluminous basis *should not* be applied *warm*, when it is intended to be copiously fixed on calico, under the operation of printing.

afterwards thickened with flour,* if intended to be printed or applied by the block and with the gum of the mimosa nilotica (gum arabic), or of the mimosa Senegal (gum of Senegal), if it be intended for penciling; and being applied in either of these ways to linens or cottons, previously bleached and made smooth by the cylinder, the latter are to be *thoroughly* dried† by a *stove heat* of 150 degrees of Fahrenheit, and afterwards put into a copper partly filled with a mixture of *cow dung* and water, through which they are to be turned by the winch, backwards and forwards, until the gum or flour employed to thicken the mordant has been dissolved, and the loose particles of alumine separated; that they may not in the dyeing vessel combine with the

* Since my former edition, it has been found that by slightly torrefying the flour, it was rendered more soluble in water, and more suitable for the purpose of giving consistency to the mordant in question; and the *brown* colour which it acquires by torrefaction supersedes the use of Brasil wood, and other colouring matters, to mark the parts which have received the mordant. Starch, by a similar torrefaction, softens, swells, and emits a penetrating odour; and, the torrefaction being *then* stopped, a substance is obtained, which has been lately much employed by calico-printers as a substitute for the gum of Senegal, under the name of British gum.

From half to three quarters of a pound of gum have commonly been found necessary to each quart of the mordant, according to the season of the year, and the sort of figures or impressions intended to be made. So much consistency should be always given to the liquor as will hinder it from spreading beyond its proper limits, taking care at the same time, that it shall retain so much *fluidity*, as thoroughly to penetrate the fibres of the calico, and, in the language of the printers, serve as a *leader* or conductor to the alumine, &c.

† This thorough desiccation, by artificial heat, contributes very much towards a more *perfect union* of the aluminous and ferruginous bases with the fibres of the cotton, by causing an evaporation of the acetic acid, and also of the water, which by their affinities, would obstruct the desired *union*.

colouring matter, and discolour the grounds intended to be preserved white. The cow dung in this operation was supposed to be useful only by combining with, and entangling the superfluous parts of the mordant, so as to hinder them when separated from the figures to which they had been first applied, from attaching themselves improperly to other parts, and becoming the basis of an unpleasant stain. But there is reason to believe that cow dung, by the gastric juices, gelatine and albumen, which it contains, affords a very beneficial impregnation to the printed calico, of some animal matter, which combining with the mordant, serves to bind it more strongly to be printed calico, and afterwards to increase its attraction for the colouring matter, like some of the *animal* impregnations which are so necessary for the Turkey red.*

* Mr. Watt has supposed that the animal *gall* contained in cow dung, exercises a particular power in this operation, of separating the acetic acid from the alumine, and that by combining with the latter, it renders it more efficacious afterwards, in attracting and holding the colouring matter in combination. Mr. Widmer, of Jouy, near Versailles, has entertained nearly a similar opinion, (as Berthollet reports); he believing that, "dans le bouzage il se forme une combinaison *triple* de la matière animale avec l'alumine et la toile, qui ajoute à la beauté des couleurs:" and for this opinion, Berthollet thinks there is some foundation, because water alone does not answer the purpose; and he adds, that an examination, *not indeed the most minute*, of cow dung, did not enable him to discover in it any thing likely to produce these beneficial effects, excepting a matter analogous to *bile*, "une matière analogue à la bile." Elémens, &c. tom. i. p. 90.

Haussman substituted powdered chalk for cow dung (with water); but found the colours which were raised afterwards upon the aluminous basis to be very feeble, though those upon the oxide of iron, which had at the same time been subjected to the action of chalk and water, did not appear greatly defective. Soap and water being employed instead of cow dung and water, produced effects more hurtful to the aluminous basis than those of chalk and water. If

Subsequently to this dunging operation, the pieces of calico are to be well rinced, and beat in clean running water, to remove as far as possible every loose particle of the mordant, which might otherwise, when in the dyeing vessel, occasion an improper stain.

By thus substituting the acetic for the sulphuric acid, in the aluminous mordant lately described, several considerable advantages are gained. The acetate of alumine being much more soluble in water than common alum, the liquor will contain a much larger proportion of alumine, than could be otherwise suspended in it; and with this advantage, moreover, that it will not be liable to form crystals in or upon the linens or cottons in drying, as would happen with a solution of common alum, the acetate of alumine being incapable of crystallization. I may add also, that the acid of vinegar being volatile, and having a much weaker attraction for its earthy basis than the sulphuric acid has, the former will be speedily separated and carried off, especially by the heat of the stoves employed for drying the pieces printed with it, and will leave behind the alumine which it had dissolved, and which, being no longer encumbered by any other attraction, will yield itself wholly to that, which subsists between it and the fibres of linen or cotton, and will unite with them more copiously and firmly than it otherwise could do, and be thereby enabled more strongly to attract and fix the colouring matters in the dyeing vessel. This, however, will only prove true, so far as the sulphate of alumine has been really decomposed by the acetate of lead, or so far as the alumine has been combined with the acetic instead of the sulphuric acid.*

cow dung were only useful by *thickening* the water, oatmeal, or the meal of lint-seed might well supply its place; but I have not found them capable of doing so.

* Since these observations were first published, *cheaper* means

As the practice of calico printing has been but lately introduced into Europe, and as the acetated aluminous mordant does not appear to have been previously known in any other country, we might have expected that its discovery in *this*, would have been deemed a matter so important, as to have constituted an æra in the history of the art; and, therefore, I was not a little surprised in finding that no writer had mentioned, and that no calico-printer, of whom I have inquired, could inform me, at what time, or by whom, this mordant was first employed, as the basis of red and yellow colours in calico-printing. My wonder has, however, ceased on this subject, since I have inspected a considerable number of recipes for making the several mixtures employed as mordants,

have been discovered of forming an acetate of alumine. White lead, not adulterated by carbonate of lime, being dissolved in strong vinegar, was found, in several experiments which I made, to answer the purpose of sugar of lead, and to produce a good aluminous mordant, by adding to the solution a suitable proportion of powdered alum; and I afterwards found that litharge dissolved in vinegar, instead of white lead, was equally useful for decomposing alum. But soon after it had been ascertained, that the acid obtained from oak, beech, and other woods, by converting them to charcoal in *close vessels*, and collecting the acid by proper tubes and receivers, was truely an acetic acid with only an intermixture of an empyreumatic oil, and perhaps a little ammonia, this pyroligneous acid was generally substituted for vinegar, and employed to dissolve the oxide or carbonate of lead; and the solution so made, was, with a considerable diminution of expense, employed to decompose alum, instead of sugar of lead; the empyreumatic oil, excepting its unpleasant smell, doing little or no harm even to the most lively and delicate colours, and proving in some degree beneficial to those depending on a ferruginous basis.

More recently, however, it has been discovered, that by dissolving lime instead of an oxide or carbonate of lead, in the pyroligneous or other acetic acid, alum might be still more cheaply decomposed; and at present, an acetate of lime is, I believe, generally employed, instead of the acetate of lead, to produce the aluminous mordant.

soon after the business of calico-printing began to be carried on with some degree of success here, and in other parts of Europe. In one of these, which seems to have been the earliest, alum, sal ammoniac, saltpetre, red orpiment, and kelp, were directed to be mixed with water. In another, which probably followed this, it was directed that these ingredients should be dissolved in vinegar. In a succeeding recipe, a little sugar of lead was directed to be employed, but in a quantity too small to be of any considerable use; I mean one ounce of it for every pound of alum. Afterwards, the calico-printers, without any system or reasonable motive, appear in different instances to have added verdigrise, arsenic, corrosive sublimate, blue vitriol, *litharge*, and *white lead.* By stumbling upon the two last (which alone were of any use), it happened, where vinegar had been also employed, as it commonly was in some shape, that after a variety of decompositions and recompositions, some portion of acetate of alumine was formed, the good effects of which were experienced, though without any true knowledge of the ways and means by which they had been produced. By degrees, however, the printers seem to have increased the quantity of sugar of lead, and several of them to have suspected that many of the other ingredients usually employed for making their mordants were useless. Some of them, therefore, began to omit one, and some another of these ingredients, until at length all the useless ones were laid aside, though without the aid of any chemical reasoning on the subject, and without any one having ever suspected, as indeed few of them do at this day, that the lead which they continued to employ, occasioned any decomposition of the alum, or that the mordant so produced did not really contain all the lead and other ingredients used to prepare it. Among the useless ingredients before men-

tioned, corrosive sublimate seems to have been retained the longest, since Mr. Wilson includes it in his recipe, which was published so lately as the year 1786. (See his Essay on Light and Colours, &c.)

It is not wonderful, therefore, that no particular person or period has been noted, or remembered, as distinguishable for the first invention of the acetated aluminous mordant; since the sugar of lead, or other means of forming it, were at first used by chance so sparingly, as to have scarcely produced any better effect than would have resulted from the mere solution of alum, and the alterations and improvements by which the mordant afterwards acquired its present form, I had almost said perfection, were made by such imperceptible gradations, and resulted so much from the random additions and omissions of different individuals, (no one of whom seems to have been guided by any thing approaching to a just theory,) that neither the discovery, nor any considerable step towards it, can properly be referred to any one person or period.

Mr. Henry, justly sensible of the superior advantages of the acetated aluminous mordant in calico-printing, and conceiving it to have really been very anciently known and employed in those countries where the art was first practised, concludes from thence, that it must have resulted from a very advanced state of chemical knowledge in those countries, at some very remote period, which was afterwards lost, whilst the improvements arising from it in this respect continued to be practised and handed down, through a long succession of ages to the present time. "To have invented (says he) the process of printing, in the manner described by Pliny, the inhabitants of India must probably have known how to prepare alum: they must have been acquainted with the manner of dissolving lead in the

vegetable acids; they must at least have been acquainted with the component parts of these salts, and they must have had a knowledge of double elective attractions, &c." In truth, however, the inhabitants of India neither had, nor have they at present, any knowledge of the use of sugar of lead, or of any other preparation of that metal which could produce similar effects in calico-printing; a solution of common alum in water being their only aluminous mordant, and the previous application of the soluble parts of myrobalans and of buffaloes' milk, to their calicoes, aided by a very *hot sun-shine*, and the complete desiccation which it produces, enabling them, without any thing like an acetate of alumine, to give equal durability to their colours. This fact I have learned, not only from all the accounts published, or transmitted to Europe respecting this point, but from the positive verbal informations of eye-witnesses to the practice of calico-printing in that part of the world, and particularly of a gentleman of great veracity, as well as knowledge on this subject, who formerly carried on the business of calico-printing very extensively in Bengal (principally for account of the East-India Company): and indeed sugar of lead is so far from being used for this purpose there, that within a few weeks I have received a letter from Mr. John Adie, (successor to the gentleman last mentioned,) dated, "Gondelpara, near Chandernagore, the 10th of February, 1792," and mentioning, that he had some little time before been obliged to pay twenty shillings the pound for sugar of lead, in order to prepare a particular colour which I had formerly recommended; so far was this ingredient from being in use there for any such purpose.

We may, therefore, safely conclude, that the formation of an acetate of alumine, and its application as a mordant in calico-printing, was not an oriental disco-

very; and that it did not result from any knowledge of double elective attractions, or any other extensive chemical knowledge, either in ancient or modern times; since those who gradually stumbled upon and introduced the use of it, were totally ignorant of the decompositions and recompositions which took place in their mixtures, and always supposed, as all other calico-printers have till lately done, and as most of them now do, that the aluminous mordant really consisted of every thing used in producing it.

To illustrate more plainly the *differences* of *colouring* matter, as well as the action of an aluminous basis upon them, let us examine its effects in a few particular instances: taking a small piece of calico, upon which certain figures and designs had been printed with the acetated aluminous mordant, and which, after being dried, had been cleansed in the usual way, I dyed it in water with saffron;* the water readily extracted the yellow colour of the saffron, and the calico soon imbibed so much of the colour, as to become *equally yellow in all its parts*, without any difference of shade, even where the alumine had been applied. The calico so coloured being exposed to air, soon became equally and uniformly white; the colouring matter of the saffron having no affinity to the alumine: to see, however, whether this last remained fixed in the fibres of the cotton, I dyed the same piece which the saffron colour had thus abandoned, in water with a little Brasil wood, and the figures, where the alumine had been applied, became of a strong, full, and beautiful crimson; the other parts, to which no

* The colouring matter of saffron readily dissolves in water, but is soon destroyed by the rays of the sun; it gives a rich yellow to linen, cotton, &c. but having no affinity for any known basis, it has no permanency, though it will acquire blueish and greenish shades, when acted upon by the sulphuric and nitrid acids.

basis had been applied, being but slightly discoloured. The calico so dyed, being exposed to the sun and air two or three days, the spaces to which no mordant had been applied became perfectly white; and the figures impregnated with alumine had lost some of their fine crimson colour, which gradually diminishing, by a continued exposure, was all gone at the end of eight days. In this instance, the aluminous basis had a certain affinity with the colouring matter of the Brasil wood, (which was not the case with that of saffron,) but not so much as to fix and retain it *permanently*. To ascertain, however, that the defect arose from the want of a sufficient affinity between the colouring matter and the alumine, and not between this last and the cotton, I took the same calico, which had been already twice dyed, and dyed it a third time in water with madder, whereby the whole became coloured, but the figures impregnated with alumine much more deeply than the other parts; a proof that the alumine still remained fixed, notwithstanding the escape of the Brasil wood crimson, and that it had again entered into a triple combination with the madder colour, and the fibres of the cotton. The piece so dyed, being well boiled in water soured with bran, and exposed to sunshine and air, in a few days became white in the parts where no mordant had been applied to fix and retain the colour, whilst the figures formed by the application of alumine, retained all their body and brightness; the colouring matter of the madder, in this triple combination, not being liable to destruction or separation by the same means which destroyed or separated it where no such bond of union or means of preservation existed.*

* M. Berthollet, in the last edition of his Elements, &c. (tom. i. p. 80) has introduced my account of these experiments, to illustrate and prove the affinities of alumine employed as a basis, and

It has been already noticed, that in oriental calico-printing the solution of alum is coloured red with sampfan or sappan wood; and I might have added, that in dyeing with chay root, the red colour of the wood is dislodged from the pores of cotton by the superior attraction of the root colour, which takes its place. Neither the East Indians, however, nor the writers who have given accounts of their operations, seem to have been apprised of this fact; but have concluded that the red wood colour was fixed, and made durable by applying that of the chay root.* To ascertain the truth on this point, I made several experiments, of which an account was given in my former edition; but they are now omitted, because those which I have since made with the *chay root itself*, and which will be stated hereafter, must render the former unnecessary.

After this account of the *acetate* of alumine, it is proper that I should notice *that* of iron, commonly called iron liquor, which, as employed in Europe, was manifestly borrowed from the Indians, with only the substitution of a vinegar from wine or malt, for that obtained by fermenting the juice of some of the different species of palm trees.

also the different dispositions of colouring matters to be acted upon by these affinities.

* This erroneous opinion has been again very lately propagated in a French periodical work, of considerable respectability, ("Annales des Arts et Manufactures," No. 51,) where M. Le Goux de Flaix, in giving an account of the chay root, says, "This root is useful not to give colour, but only to fix that which has been otherwise given;" and he adds, that by not knowing this fact, it was found impossible to make any use of a large quantity of the chay root, imported by the French East India Company to France, in the year 1774. The true cause, however, of the failure here mentioned, will be explained hereafter, when I shall have occasion to notice a similar failure, in regard to a recent importation into this country, by the English India Company.

The means of producing an acetate of iron, obviously presented themselves, and did not require any more chemical knowledge, than people but very moderately civilized are commonly found to possess. Iron, in a state proper for being dissolved by vinegar, might be procured, without a previous decomposition for that particular purpose. But this was not the case with *alumine*, of which the nature was completely unknown, as well as the ways of procuring it; and even at this time, though we know it to be a particular and *pure species* of clay, we do not find it either practicable, or advantageous, to obtain it, except by separating it from the sulphuric acid, with which it has been previously dissolved, and combined in *common alum*.

The first European calico-printers, in making their iron liquor, employed many useless ingredients, as they also did in making the aluminous mordant. In the more early prescriptions I have found, besides old iron, and vinegar or sour beer, verdigrise, sugar of lead, blue vitriol, antimony, urine, the brine of pickled herrings, saltpetre, sal ammoniac, and other *incongruous* matters, frequently directed; and they were thought to be useful, because they did not *hinder* the oxide of iron from performing its office as a basis. Rye meal was for many years very commonly employed, and probably with some advantage. Afterwards, however, experience, directed by the light of chemistry, enabled the manufacturers and consumers of this mordant, gradually to discard the useless ingredients employed in making it, as they also did those which had for a considerable time encumbered, and in some degree injured the mordant, from alum. Iron alone, dissolved by an acetous acid, then constituted the iron liquor; and to produce this acid, malt, or sour beer, or the *washings* of sugar hogsheads, were commonly employed, as being the most

economical; and broken iron hoops, or other thin pieces of old iron, were subjected to the slow action of the acid. And when a more concentrated solution was wanted, either as the basis of very full adjective colours, or as a substantive topical colour, certain proportions of sulphate of iron were dissolved in the iron liquor, which, with or without this addition, always required to be thickened, like the aluminous mordant, when topically applied by the pencil, or printed by engraved blocks.

I scarcely need to add, that since the nature of pyroligneous acid was ascertained, this last has been preferred, as the cheapest, and in some respects most useful, for making the acetate of iron, as well as that of alumine.

When pieces of calico have been printed with iron liquor, whether it be applied to those which either have received, or are intended to receive, the aluminous mordant also, they are to be thoroughly dried by a *stove* heat, and afterwards passed through the mixture of cow-dung and warm water, in the manner directed for pieces which have been printed with the acetate of alumine only, and with a view to similar effects; and they are afterwards, in the language of the calico-printers, to be *streamed*, or extended, in running water, and beat, to remove all the loose or uncombined particles of the mordant, and thus fit them to be dyed, with either madder, sumach, weld, or quercitron bark; these being the principal, and almost the only adjective colouring matters so employed by calico-printers, and sufficient (excepting the blue from indigo) to produce, with the aluminous and ferruginous mordants, all the various colours seen and admired on printed calico.

E. G. If pieces of calico, to which these mordants have been applied both separately and mixed, be put

into a dyeing vessel, with water scarcely blood-warm, and in which three, four, or five pounds of madder in powder, for each piece, have been previously mixed, and they be turned, as usual, through the liquor, by the winch; gradually, but slowly, raising the heat, so that it may only reach the boiling point at the time when the calicoes will have been sufficiently dyed, the several pieces will be found to have imbibed colour in every part. The figures or places to which the unmixed iron liquor was applied, will have been dyed black, and those on which the aluminous mordant was printed, will be red, of different shades, if the mordant had been used at different degrees of concentration; and, if both mordants were mixed and applied in different proportions, such applications will have produced various shades of purple, violet, chocolate, and lilac colours; whilst the parts, or *grounds*, intended to be ultimately left white, will manifest a considerable brownish red discoloration: but as the madder colour producing it, is not then united to the calico, by the affinity or attraction of any intermediate basis, it will not be able, *as in other parts*, to resist the action of exterior agents, and may therefore (as is usually done), be removed, and the grounds made *white*, by boiling the pieces in water soured by fermented bran, and by afterwards spreading them for some days (according to the season) upon the grass; where, with the well known treatment, the colours dyed upon *a basis* will become brighter, whilst that *without one* will completely disappear.

Calico, printed with the same mordants, and dyed with the quercitron bark, (quercus tinctoria, or quercus nigra, Linn.), will acquire fixed and bright yellows of different shades, upon the aluminous basis, and various drab colours upon that of iron. A mixture of these bases will produce olive colours. Along with these it is

usual to produce black impressions at the same time, by previously applying to the calico a mordant composed of iron liquor and galls; by which figures, which, without the galls, would only have manifested a dark drab colour, are made *black*, by dyeing with the quercitron bark; and if the dyeing be conducted as I shall hereafter direct, the grounds will be so little discoloured, that no exposure upon the grass will be required, as is necessary with madder and weld; an advantage which has nearly put an end to the use of weld in calico-printing.

This method, however, of *dyeing* yellow upon a *basis*, is an European invention; the people of India having only given it, as already mentioned, by a *pro-substantive* mixture of the decoction of the galls of myrobalans with alum. And, indeed, this practice was followed here for some time after the introduction of the art into Europe, excepting that, instead of the galls of the myrobalan tree, a decoction of French berries (rhamnus infectorius, Linn.) was employed; by which, indeed, a very full bright yellow was at first communicated, but of so *fugitive a nature*, that the use of these berries, which in some degree still subsists, ought to be discouraged; it being impossible, by any means yet known, to obtain from them a colour fit for any other purpose than that of deception.

Hitherto, the art of calico-printing has been confined almost solely to linens and cottons, which are suited to it, by being susceptible of a permanent union with colouring matters, and especially with their bases, by only the common warmth of the atmosphere: and as this is also the case of silk, there can be no doubt but this last might be made the subject of new and beautiful embellishments in that way, which, if properly executed, would undoubtedly become a source of gratification to the public, and of profit to individuals.

Very lately indeed a species of topical dyeing or staining, very much resembling some parts of calico-printing, has been ingeniously applied to woollen stuffs, and particularly those called kerseymeres, for waistcoat patterns, &c. What I mentioned in a former chapter, of the necessity of a considerable degree of heat, to enable the fibres of wool to receive and combine with colouring matters, will afford some idea of the difficulty of applying and fixing different colours in the form of spots or figures upon woollen stuffs in this way by dyeing; the particular mode and means by which this difficulty is overcome, and the several colours fixed in the fibres of wool, are still kept secret as much as possible. How proper colours for this purpose may be provided, either from substantive colouring matters, or from the adjective ones, made into the form of a strong decoction, and mixed with the proper mordants, (as in the instance which I lately noticed of a pro-substantive yellow,) will be easily understood by those who may attend to what has been, or will be, explained in the course of this work; and such colours being so prepared, and printed upon kerseymere, &c. in the usual ways, may be, as I have found on trial, and as I am informed they are, made to penetrate and unite with the wool, by placing the stuff so printed in the steam of boiling water for a sufficient length of time, first wrapping it up in thick paper, doubled or trebled, so as to exclude the moisture, so far at least as that it may not occasion the colours to run beyond their proper limits.

After this summary account of the origin, progress, and nature of calico-printing, intended to illustrate more distinctly the effects of the principal bases or mordants, it will be proper here to take a general view of the facts which respect the application of these bases, for fixing and modifying different adjective colours, not by topical,

but by general dyeing, as well upon wool and silk, as on linen and cotton.

The two last of these, spun into thread or yarn, and either woven or not, are made fit for the application of a basis, by being boiled, for the space of three or four hours, in a solution or lye of potash or of soda, of suitable strength; then spread for some time on the bleaching-ground; afterwards soaked in water, made sour by the addition of one-fiftieth, or sixtieth, of its weight of sulphuric acid, or oil of vitriol; and finally rinced thoroughly in clean water, and dried. When thus prepared, if the aluminous basis is intended to be applied to them, perhaps there is no form in which it could be more effectual than that of the acetated aluminous mordant, though motives of economy have always induced the mere dyers of linen and cotton to employ cheaper preparations of that basis. The sulphate of alumine, or common alum, will indeed yield a part of its earthy basis to linen and cotton, when dissolved by water and applied to them; but it does this more readily when deprived of its excess of acid by potash or calcareous earth; and it is in this way commonly employed as a mordant for linens and cottons. About four ounces of alum, with water sufficient to dissolve it, and half an ounce, or somewhat less, of potash, are commonly allowed for each pound of linen or cotton intended to be dyed; and the latter are to be macerated, &c. in this liquor, cold, or only blood-warm, until thoroughly and equally penetrated by it, and afterwards well rinced, to separate the superfluous or loosely adhering alum, &c.*

* If, instead of the small proportion of potash here mentioned, so much of it, or of soda in its stead, were employed, as would suffice first to precipitate, and afterwards re-dissolve, the alumine, the latter, being then in a triple combination with the acid and alkali,

Cotton, treated in this way, commonly gains about two and a half per cent. additional weight by the alum, partly decomposed, which combines with it. But, where no white grounds are to be reserved, there are ways of separating the aluminous basis more advantageously, and applying it more efficaciously, particularly for madder colours upon linens and cottons, by impregnating them with oleaginous, astringent, glutinous, animal, and alkaline substances, which occasion an increased affinity or attraction between the fibres of the linen or cotton and the colouring matters; thereby forming, perhaps, a kind of cement, which renders them more fixed, and less liable to be acted upon and injured by those causes which generally destroy or weaken colours. These auxiliary means will hereafter be noticed in their proper places, and particularly when treating of the Turkey red.

Silk is to be impregnated with the aluminous basis, by macerating or soaking it only, during the space of ten or twelve hours, in a saturated cold solution of alum.

To impregnate wool or woollen cloth with the aluminous basis, it is commonly boiled in water, with from one fourth to one-sixth of its weight of alum, and from one-twelfth to one-sixteenth of its weight of crude tartar, putting the latter first into the water, and, afterwards, the powdered alum: the heat of the water being gradually raised, is kept at the boiling point for an hour and a half, or two hours, during which the cloth is turned through the boiling liquor on a winch, that the mordant may be equally applied; and being afterwards taken out and drained, it is commonly left until the next day, and then rinced in clean water, for dyeing. In the early col-

would be less attached to either, and more readily, as well as copiously separated, and united with the fibres of linen or cotton.

lection of recipes, printed in 1605, and already mentioned, *sour bran* liquor is commonly directed to be employed in this way with alum; and it seems to have answered the purpose of tartar, which, when it came to be generally used in this way with alum, was supposed by the older dyers to do good by *softening* and *correcting* the acrimony of the latter: probably, however, the purposes which it answers, are not yet clearly ascertained; one of them seems to be, that of increasing the solubility of alum, and enabling it more completely and intimately to penetrate the fibres of the wool, with which it moreover enters into a permanent union, and thereby contributes efficaciously to modify, vary, and in some cases to brighten the colours with which it is employed, as will be seen hereafter.

It was until very lately believed, even by those who had most knowledge of the subject, that woollen cloth boiled in this way, with alum, decomposed the latter, in a considerable degree at least, attaching to itself the alumine, though not without a small portion of the sulphuric acid in combination therewith.* Very recently, however, MM. Thenard and Roard (of whom, the latter is director of the dyeing department at the imperial manufactory of the Gobelins at Paris,) appear to have acquired more correct ideas on this point, by a series of experiments, of which they have given a minute statement, in a memoir read at the Physical and Mathematical class of the French National Institute, (see Ann. de Chimie, tom. 74, p. 267.)

* Berthollet, tom. i. p. 80, after saying, that in aluming stuffs the latter decompose the alum, and combine with the alumine, whilst the acid which held it dissolved, separates and remains in the bath, adds, "Mais il ne faudrait pas conclure de là, qu'aucune portion de l'acide ne reste dans la combinaison de l'étoffe où elle peut avoir quelque influence sur la couleur."

These experiments were principally made with alum, acetate of alumine, tartar, and the solutions of tin, applied to wool, silk, and cotton; and by these, it was fully ascertained, that alum and cream of tartar do not decompose each other when dissolved in water, and boiled with wool, (a fact which had, indeed, been previously asserted by Berthollet); that in this boiling, the wool combines with the alum, *without decomposing it in any degree*,* and also with the tartar; that equal parts of alum and tartar would dissolve in two-fifths *less* of water, than would be required to dissolve them separately.

They found that wool, as it is commonly *cleansed* for being *alumed*, was not deprived of the carbonate of lime naturally combined with it; and that this wool, being boiled the usual time, with one-fourth of its weight of alum, and one-sixteenth of its weight of cream of tartar, rendered the bath, or water, troubled or muddy, and

* It was completely ascertained, that when wool had been so *alumed*, the alum employed might be all recovered, partly from the bath or liquor in which the aluming had been performed, and partly from the wool itself, by repeatedly washing the latter in pure boiling water: commonly a dozen separate washings were sufficient to remove completely all the alum which had united itself to the wool; and the alum, so separated, was susceptible of a distinct crystallization, as if it had never been so employed. After the last of these washings, the wool or cloth, so washed, was found to be as incapable of receiving colours by dyeing, as if it had not been alumed; and, indeed, *before the last*, it was always found, that the colour attempted to be dyed upon it, was feeble, in proportion to the number of washings which had taken place.

It became evident, therefore, from these experiments, that wool or cloth boiled with alum (and tartar) attached to itself the *undecomposed alum only*, and that a decomposition of the latter does not take place until the subsequent operation of dyeing, when the affinity of wool, being assisted in the dyeing vessel, by the affinity of the adjective colouring matter, their *co-operation* separates the alumine, in a great degree at least, from the sulphuric acid.

produced (as is, indeed, commonly observed), a copious white sediment, which being collected, washed, and analysed, was found to consist chiefly of a sulphate of lime, and a saturated sulphate of alumine. That when wool had been properly cleansed, and deprived of its carbonate of lime, no sulphate thereof was found. Such wool or cloth, being boiled in pure distilled water, with the proportions just mentioned of alum and tartar, and the bath or liquor with which the boiling had been performed being carefully evaporated, a residuum was found, consisting of alum, cream of tartar, and a compound, difficultly crystallizable, of tartrite of potash and animal matter. The wool itself, when so boiled, afforded, by repeated washings, alum, and a small quantity of cream of tartar, besides a very sour combination of tartaric acid, alum, and animal matter. As the acid of tartar combines so copiously with wool, MM. Thenard and Roard have inferred, that it ought not to be employed in this way with alum, except for colours which acids contribute to raise and improve; and among such colours they rank those of cochineal, kermes, and madder; but those of weld, logwood, and Brasil wood, not resisting acids as they suppose, wool, intended to be dyed from either of these, ought, as they think, to be alumed, without any addition of tartar. The accuracy of these opinions will be tried by facts, when the several colouring matters here mentioned shall claim our particular attention.

These gentlemen did not find any advantage to arise by a prolongation of the boiling with alum and tartar beyond the space of two hours, nor by increasing the proportions of alum and tartar; but, on the contrary, thought they observed beneficial effects from a diminution of them with weld, logwood, and Brasil wood, but not with cochineal, madder or kermes. Nor did they

find any benefit produced, by letting the wool or cloth remain some days in the liquor with which it had been boiled, as some persons have advised.

From these experiments, MM. Thenard and Roard have thought themselves entitled to conclude, with "*certitude*, que dans l'alunage de toutes les matières animales, l'alun *se combine en entier* avec elles, sans éprouver aucune décomposition, et qu'il forme alors des combinaisons plus ou moins solubles, qui ont pour les matières colorantes une grande affinité;" and they have made a similar conclusion in regard to vegetable matters, (i. e. linen and cotton, &c.); having found that the latter, when carefully alumed, might be completely deprived of every particle of alum, by fewer washings than silk, and by *much* fewer than wool, which had been so alumed. They found also that, (as with *silk*,* and for similar reasons), it was always best to begin the dyeing of linen and cotton (when alumed) at a low temperature, and to keep the dyeing liquor considerably below the boiling point, until the colouring matters were enabled to attach themselves to the mordant, and produce an insoluble combination therewith, previously to its being subjected to the action of *boiling* water.

These gentlemen, moreover, ascertained, that when acetate of alumine was applied to wool, silk, linen, and cotton, it combined with them entirely, undecomposed, like alum; but, being exposed to a warm atmosphere, a part of the acetic acid, from its volatility, soon evaporated, leaving behind an *excess of alumine*, which could

* Silk ought never to be subjected to a *boiling* heat, either when the mordant is applied, or afterwards, in the dyeing operation; where a high temperature, besides injuring the texture and lustre of the silk, would detach and separate the mordant, before the colouring matter could have combined and produced an insoluble union with both.

not, like the mere acidulated acetate of alumine, be carried off by boiling water: a fact which accords with the explanation lately given of the utility of this mordant in calico-printing.

In regard to the solutions of tin, it appears, that woollen cloth, boiled with them in water, and the proportion of tartar which is commonly employed in dyeing scarlet, combined with the acids, as well as with the oxide of that metal; and that by numerous washings afterwards with distilled water, boiling hot, all these matters were completely separated; and that by evaporating the washings, they were collected in the form of tartaric acid, and muriatic acid, combined with tin; while the mother water contained (as was also ascertained by evaporating it) tartrite of potash, acidulated tartrite, and a very acid muriate of tin. It results, therefore, from these experiments, that wool has no more power to decompose the solutions of tin, than it has to decompose those of alum; and that, when not assisted by the affinity of some colouring matter, it unites with both the tin and the acids, holding them in solution.

The different solutions of tin, the best means and methods of producing them, and their respective effects in dyeing, will be noticed hereafter; and more especially when I come to treat of the dyeing of scarlet with cochineal, for which that metal was first employed as a mordant, and with advantages so remarkable, that the discovery of its use for that purpose, may be considered as an important æra in the history of this art.

The mordants afforded by iron, when employed upon wool and silk, are commonly applied either subsequently to, or interchangeably with, the colouring matters intended to be fixed or modified by that basis, as will be more particularly explained, when the dyeing of black claims our attention.

It will be ascertained hereafter, by my own particular experiments, that all the metals, properly so called, as far as they have been tried, are capable of attracting adjective colouring matters in some degree, and of serving as bases to them; and this is also true of most of the earths; though none of them is so efficacious and useful in this way as alumine; indeed this, and the oxide of tin, seem to be the only bases suited, by their perfect *whiteness*, to reflect the rays of light so as to exhibit adjective colours with their utmost lustre and brightness, every other falling short of these in that respect, and almost all of them appearing to sadden or darken the colours which they serve to fix. Probably, the oxides of zinc and antimony do this less than any of the others: the former, however, (zinc) does not appear, by my experiments, capable of giving *much* stability and permanency to *any* colour dyed with it.

After this *general* explanation and illustration of the properties and uses of mordants or bases in fixing and modifying adjective colours, I shall next proceed to a *particular* inquiry concerning their effects upon *each* of the more important dyeing drugs of this class, beginning with those which belong to the *animal* kingdom.

CHAPTER II.

Of Adjective Colours from European Insects, and principally from the Kermes, *or Coccus Ilicis, Linn.*

"La laine et la soie qui montreroient plutôt dans leur couleur naturelle la rusticité "de l'age, que l'esprit de l'homme et la politesse du siècle, n'auroient qu'un médiocre "commerce, si la teinture ne leur donnoit des agrémens qui les font rechercher et "desirer, même par les nations les plus barbares."

COLBERT, *Instruction générale pour la Teinture, &c.* 1672.

AMONG *animal adjective* colours, the *kermes* are entitled to our *first* notice, because they appear to have been used for dyeing at a very early period; and, like the murex and buccinum, were probably first employed for that purpose by the *Phœnicians*. Being unacquainted with the oriental languages, I can only adduce to this point the opinions of others, better qualified than myself in that respect. One of these is Professor Tychsen, (quoted by professor Beckman, vol. ii. p. 185 of the English translation of his History of Inventions,) who says, that among the Hebrews, the kermes dye was mentioned, under the names of "*tola schani*, or simply *tola*, by their oldest writer, Moses;" that "*tola* is properly the *worm*," and that "the additional word *schani*, signifies either double dyed, or, according to another derivation, bright, deep, red dye;" that for the shell "purple, the orientals have a particular name, *argaman* or *argevan*, which is accurately distinguished from *tola*;"—"all the ancients, therefore, translate the Hebrew word *tola* by κοκκος, Kermes, zehori, and zehorito, (deep red, bright dye,) which words they never put for argaman." After these and other observations, he concludes, that "the scarlet, or kermes dye was known in the East, in the earliest ages before Moses; and was a discovery of Phœnicians in Palestine, but certainly not of the small wandering Hebrew tribes."

That "tola was the ancient Phœnician name used by the Hebrews, and even by the Syrians; for it is employed by the Syrian translator, Isaiah, chap. i. v. 18."—"Among the Jews, after their captivity, the *Aramæan* word *zehori* was more common."

Bischoff also maintains, that the kermes red dye was meant by the Hebrew words tholaat schani, in several parts of the Old Testament. It may, therefore, be assumed, that the colour which is mentioned in Exodus, chapters xxvi. xxviii. and xxxix. (as one of the *three* which were prescribed for the curtains of the tabernacle, and for the "holy garments" for Aaron,) and which the English translators have rendered by the word *scarlet*, (as they have done in other parts of the Old Testament) was no other than the blood-red colour, dyed from the kermes. Indeed the colour now denominated scarlet, and dyed from *cochineal*, upon a *tin basis*, had not been discovered when the last English version of the Bible was made, in the reign of James the First.

The Greeks appear to have obtained a knowledge of the kermes, and their use in dyeing, at a much later period; and we find this insect denominated κοκκος βαφικη by Dioscorides, iv. 48, p. 260, and by other Greek writers: whence the Latins derived their names of *coccum* or coccus, with the addition of infectoris, or infectorium. Pliny, as I have noticed at p. 93, mentions the kermes as being sometimes employed, conjointly with the colour of the murex and buccinum, in producing a sort of purplish crimson, called by the Romans *hysginus*. He adds, upon that occasion, that this drug was brought from Galatia, or from the vicinity of Emerita, in Portugal, and that the *latter* was the most commended.* And again,

* "*Coccum* Galatiæ *rubens granum*,"—"aut circa Emeritam Lusitaniæ, in maxima laude est." Plin. Hist. lib. ix. c. 41.

in his 16th book, chapter viii., after describing various uses or products of the oak, he mentions the coccum, or kermes, as being the most excellent; adding, that it is an excrescence, produced upon the stems of a small shrub, called the *ilex* aquifolia;—but of such value, that the people of Spain are enabled to discharge half their tribute by it; and that it is also produced in Galatia, Africa, Pisidia, &c. Lastly, Pliny, in the second chapter of his twenty-second book, after noticing the great improvements which had been then recently made in the art of dyeing, mentions (while he professes to pass over) the grains brought from Galatia, Africa, and Portugal, and *appropriated for dyeing the imperial robes*, &c.*

The ancients had but very incorrect notions of the kermes, many supposing them to be the grains or fruit of the ilex. They saw, indeed, that insects were ultimately evolved or produced from them; but believing, as they did, that insects might be spontaneously generated by corruption, this evolution did not appear incompatible with their supposition, that the kermes was properly the grain, or berry, of the tree on which it was found.

From the name of coccum or coccus, cloth dyed red with kermes was designated by the substantive coccinum, and the adjective coccinus, or coccineus;† and

* "Atque ut sileamus, Galatiæ, fricæ, Lusitaniæ granis, coccum *imperatoriis* dicatum paludamentis," &c.

† Corresponding designations were given in the original Greek, as well as in the Latin version of St Matthew, xxvii. v. 28, to the *robe* which our translators denominate *scarlet*, and with which the soldiers clothed and derided *Jesus*, when having "platted a crown of thorns, they put it upon his head, and a reed in his right hand, and they bowed the knee before him, and mocked him, saying, Hail, king of the Jews." The fact shows, that the kermes red was then considered as an attribute of *royalty*.

persons wearing such cloth were said to be *coccinati*, according to the following line of Martial, viz.

"Qui *coccinatos* non putat viros esse."

It will have been seen, by the passages which I have recently quoted from Pliny, that the appellation of *granum* was given by him to the kermes insect, doubtless from its resemblance to a grain or berry; and this appellation has been continued by succeeding writers*, and, doubtless, occasioned the colours dyed from the kermes to be called *grain*, or *ingrain* colours, as those of cochineal afterwards were, from a similar mistake, which for some time subsisted, concerning the nature of that insect.

By a succession of observations, however, it seems to have been ultimately ascertained, that the worm or insect was the most important part of the supposed grain or berry in producing the kermes red, and, therefore, in what have been called the middle ages, this production was frequently denominated *vermiculus*, or *vermiculum*, and the cloth dyed with it vermiculata; and hence ultimately originated the French word *vermeil*, and that of *vermilion* derived from it.

The Spaniards, and through them the other nations of Europe, appear to have obtained the name of *kermes* from the Arabians, who, according to their own accounts, were made acquainted with it, as well as the substance, by the Armenians† and Persians, among

* In modern times, the kermes have been called by the Italians, *grana da tintore;* by the Spaniards, *grana de tinctores;* by the French, *graine d'escarlate;* and by the English, kermes *berries*.

† Beckman says, that J. Beithar, in Bochart *Hierozoicon*, ii. p. 625, calls kermes an Armenian dye; and that the Arabian lexicographers, from whom Giggeus and Castellus made extracts, explain the kindred word *karmasal*, (coccineus seu vermiculatus) as an *Armenian* word. It is notorious that the insects in question

whom (as has been mentioned by Dioscorides, Dodoneus, and others) kermes was an indigenous production, and had for many ages been employed in dyeing. By thus adopting the name of kermes, the Italians afterwards produced from it the words *chermisi*, *cremesino*, and *chermesino;* and the French those of carmesin, carmine, and cramoisi; whence the English word crimson was borrowed.

The origin or derivation of the name escarlatum, scarletum, scarlata, squarlata, scarlatina, or scharlatica, from which the French escarlate or écarlate, and the English *scarlet* have been formed, is more uncertain: Pezronius thought it of Celtic extraction; and that it signified *galaticus rubor*. (See Antiq. Celt. p. 69.) But according to Beckman, *Stiler* asserts that *scarlach* is a German word, compounded of *schor*, fire, and *lacken*, cloth; and consequently that it signifies *fire-coloured cloth:* while Reiske, on the contrary, derives the words in question from the Arabic *scharal*, meaning the kermes dye.

It may be observed in favour of Stiler's assertion,

have long been produced and employed for dyeing, both in Armenia and Persia; and that they were there called *kermes*, may be proved among other testimonies by the following extract from Sir John Chardin's account of Persia, published in Harris's Collection of Voyages, where, treating of *Media*, he says, "they gather cochineal, though in no great quantity, nor for any longer time than eight days in summer, when the sun is in Leo; for before that time the people say it doth not come to maturity; and after it, the *worm* from which they draw the cochineal, makes a hole in the leaf in which it grows, and is lost. The Persians (he adds) call cochineal *kermes* from *kerm*, which signifies a *worm*, because it is extracted out of worms." It can hardly be necessary to remark, that the term cochineal is here improperly used, and that nothing more is meant by it, than the colouring matter of the kermes; which continues, according to the best information that I can procure, to be employed in a great part of India, as well as Persia, particularly for the dyeing of silk.

that the kermes red has in different ages been compared to the *colour of fire.* I have seen the words "*ardenti* radiabat Scipio *cocco*," in some of the Latin classics, though I cannot recollect which. And Bischoff, on the authority of Muratori,* mentions an old charter or contract passed in the year 1194, between the cities of Bologna and Ferrara, by which a duty was to be levied in the former of these cities, upon the grana de *Brasile*, meaning kermes, (and upon indigo); and he adds, that these Brasilian grains, and also Brasil wood, are mentioned in other old charters, particularly one dated in 1198, and another in 1306, under the name of *Braxilis;* and he concludes, with great probability, that this, and the word *brasilis*, were derived from *bragio*, a *burning coal;* in the French *braise:* and we shall accordingly find hereafter, that *red* dyeing woods, similar to that now called *Brasil* wood, were distinguished by that name, before any such wood was known or suspected to be produced in that part of America now called Brasil; and that this name was given to that country many years afterwards, when the wood came to be thence imported; and consequently that the country obtained the name from the wood, and not the wood from the country.

At what time the words from which our scarlet was derived were first used, cannot, I believe, now be accurately ascertained; the most early employment of them, of which I have found an instance, is that which Beckman has quoted from the Historia Gelrica Pontani, (Hordervici 1639,) in which, about the year 1050, the emperor Henry III. conferred upon the Count of Cleves, the Burgraviate of Nimeguen, on the condition of his delivering to him annually three pieces of scarlet cloth,

* Dissert. de Mercatibus et Mercatura sæculorum rudium, tom. ii.—Antiquitat. diss. xxx. p. 898.

made of English wool ("tres pannos *scarlatinos anglicanos*.") Beckman also refers to a document in Lunig's Codex Diplom. Germaniæ, ii. p. 1739, by which the emperor Frederick, in 1217, conferred on the Count of Gueldres, the hereditable jurisdiction of Nimeguen, on condition that he and his successors, "de eodem telonio, singulis annis tres pannos *scarlacos* bene rúbeos anglicenses *ardentis* coloris assignare deberet." The selection of English cloth, in these instances, demonstrates the high estimation in which it was held even at those periods. Beckman also refers to "Gervasii Tilberiensis Otia Imperialia ad Ottonem iv. Imperatorem, iii. 55;" a work written in 1211, in which the author alluding to the kermes says, "Vermiculus hic est, quo tinguntur pretiosissimi regum panni, sive serici, ut examiti, sive lanei, ut *scharlata*." And he then mentions it as wonderful that neither linen, nor any other vegetable substance, would permanently take this dye, "sed sola vestis quæ ex vivo animanteque, vel quo vis animato decerpitur." He afterwards mentions the shrub on which the kermes were found, and, like Dioscorides, compares the latter to *peas*, in regard to their shape and size; adding, "cum enim tempus solstitii æstivi advenerit, ex seipso vermiculos generat, et nisi coriis subtiliter consutis includerentur, omnes fugerent, aut in nihilum evanescerent. Hinc est quod vermiculus nominatur, propter dissolutionem quam in vermes facile facit, ex natura *roris maialis, a quo generatur;* unde et illo tantum mense colligitur." We see by the latter part of this extract, that the kermes were not at that time, as at present in France and Spain, *killed* by being sprinkled with vinegar and dried in the sun; and therefore, to prevent their ultimate escape, they were secured by being put into leathern bottles.

Besides these instances of the early mention of scar-

let, it occurs in several books, written in the thirteenth century; such as the History of Spain, by Roderick archbishop of Toledo, (lib. vii. 1.), which was finished in 1243; and in some quoted by Vossius, "de vitiis sermonis, 4°." Others might be added to these, were they necessary.

At the periods when the terms escarlatum, &c. were thus employed, the art of dyeing *purple* from the murex and buccinum was lost in the western empire, and the kermes dye, which in former times had been almost as much esteemed, was become pre-eminent and unrivalled; and so it continued, until the introduction of cochineal, from America, (to be noticed in my next chapter) which has, in great degree, put an end to the use of kermes in Europe, though the acorn-bearing shrub, which the ancients called ilex, (and which, in the Linnæan system, is denominated quercus coccifera,) still grows, and furnishes these insects, in all the countries mentioned as formerly producing them; and though the insects themselves continue to be employed in other parts of the world, and with great reason, for in truth they are capable, as my own experiments prove, of giving every colour which can be obtained from cochineal with equal beauty and vivacity, and perhaps with even greater permanency.

The first volume of the Philosophical Transactions contains a paper, written by M. Verney, then of Montpellier, respecting the natural history of the kermes; and M. Reaumur afterwards described them very minutely in the fourth volume of his "Mémoires pour servir à l'Histoire des Insectes." But the most useful information on this subject seems to be that which M. Chaptal lately gave to M. Berthollet, and which he has published in the second volume of his "Elémens de l'Art de la Teinture." By his account, the male insect passes

from its vermicular state, through the usual forms, into that of a fly with four wings; though the female never acquires any wings, but fixes herself on a leaf of the oak, where, being impregnated by the male, her size gradually increases (as the eggs enlarge) to that of a juniper-berry, and she at the same time becomes of a reddish brown colour. When the eggs are on the point of hatching, the females should be collected, and exposed to the steam of vinegar, to kill them, and prevent their young from being brought forth; and afterwards they should be dryed, by being spread out on cloths, by which treatment they acquire the colour of red wine. M. Chaptal says, that a single person may collect from one to two pounds of kermes in a day. But it would require ten or twelve pounds to produce the effect of a single pound of cochineal; and as the kermes, probably, could not be obtained in any quantity for less than half-a-crown the pound, the colour which they afford, would prove more costly than that of cochineal, at the price which the latter has commonly borne previous to the present war.

Hellot tells us, chapter xii. that the red draperies of the figures exhibited in the ancient Brussels and other Flemish tapestries, were all dyed from kermes, and that this colour, which in many of them has subsisted more than 200 years, has lost but very little, if any, of its original vivacity: and Beckman represents this as being true of some pieces of tapestry, which are believed to have been dyed with kermes as early as the twelfth century. The fine red or crimson colour of these tapestries, which was originally called simply scarlet, took the name of *Venetian* scarlet, after the cochineal scarlet upon a tin basis was discovered, because, as Hellot mentions, it continued to be extensively dyed at Venice, long after it had become unfashionable in other parts of Europe; though it appears, from my own particular experiments,

that if the kermes, like the cochineal, had been employed with a solution of tin by nitro-muriatic acid (instead of alum), a colour might have been obtained, which it would have been difficult, if not impossible, to distinguish from the cochineal scarlet.

To dye the Venetian scarlet, the wool, according to Hellot, was first boiled for half an hour in water, with about its weight of bran, tied up in a bag; it was then removed into another vessel, and boiled two hours in water acidulated by fermented bran liquor, with a fifth of its weight of Roman alum, and half as much red tartar; leaving the wool, after taking it out of this vessel, moistened with the same liquor, during six days; at the end of which, it was dyed in clean soft water, with powdered kermes, allowing twelve ounces of the latter for each pound of wool, and even sixteen ounces, if the kermes had suffered by age.*

When the very extraordinary effect of a solution of tin, in giving vivacity and lustre to the colour of cochineal, had been discovered, (as will be mentioned hereafter,) it might have been expected, that the influence of this mordant upon the kermes colour would have been tried, as a matter of course, but I cannot any where find that this was done; and it was not until I had dyed broadcloth in the way, and with the means commonly employed to produce the scarlet colour, substituting only

* In a letter written by Mr. William Kirkpatrick to Dr. Anderson, lately Physician-General in the service of the East-India Company, and dated *Hyderabad*, June 14th, 1796, I find the following passage, viz. "The silk-dyers at this place do not know how, I believe, to produce a scarlet. To dye a prime crimson, they employ, to one seer of silk (fresh and white) one quarter seer of kermes, one quarter seer of alum, and one quarter seer of flowers of pisteh (pistachio,) which I take to stand in place of the gall. The enclosed is a specimen of their prime crimson." If this account of proportions be accurate, the kermes of India must yield more than twice as much colour as that of Europe.

kermes for cochineal, in the proportion of twelve ounces of the former for one of the latter, that I satisfied myself of the practicability of dyeing with the kermes a scarlet colour, in every respect as beautiful and estimable as any which can be dyed with cochineal; and, consequently, that if the mordant from tin had been properly employed with the kermes, there could have been no reasonable motive for giving a preference to cochineal, unless it was found to be ultimately cheaper than the kermes, by reason of the much greater proportion of colouring matter afforded by it.

Cotton being topically impregnated with the acetate of alumine, as for calico-printing, and one-half of it being dyed with kermes, it took a full bright crimson, as the other did at the same time with cochineal; and the colours so dyed, (which in appearance were exactly similar,) being washed and exposed to the sun and air, manifested a considerable degree of permanency, though not sufficient to make it proper to employ them in this way, without an addition of madder; the yellowish red colour of which is greatly improved by the bright crimson of either of these insects. I have thought, in this and other experiments, that the colour of the kermes was a little more durable than that of the cochineal; not from a difference in the colouring matters of the insects, but from the *astringent* vegetable matter, or juice of the oak, which always accompanies the kermes.

Subsequently to my former edition, I procured a very sufficient supply of kermes from the South of France, and have tried them with nearly all the metallic and earthy bases or mordants, and always with very nearly the same results as were obtained with the like bases or mordants from cochineal, and of which an account will be given hereafter; and I conclude, therefore, that the animal part of the colour of the kermes is *exactly similar* to the colour of cochineal.

ART. II. *Coccus Polonicus.*

This is a small round insect, in many respects similar to the kermes, and employed for nearly the same purposes, until the introduction of cochineal caused the use of it to be abandoned, at least in the greater part of Europe. It was mostly collected in the Ukraine, and other provinces of Poland, (under the name of *Czerwiec*,) and also in the great duchy of Lithuania, from the roots of the German knot grass, or perennial knawel (scleranthus perennis, Linn.) The male only, by a transformation similar to that of the male kermes, becomes a fly, though with but two wings, which are white, edged with red. The females being impregnated by the male, enlarge their size, and become ready to bring forth their young soon after the summer solstice, at which time they abound most in a crimson juice, which even now is much esteemed and employed by the Turks and Armenians for dyeing wool, silk, and hair, and also to stain the nails of women's fingers. Wool and silk were prepared to receive this dye with the same mordant (of alum and tartar) as that used for the kermes. Several writers have mentioned the coccus polonicus (sometimes called the cochineal of the north); but the best account of it seems to be that given by Breynius in the Act. Natur. Curiosor. of the year 1733. There is also an account of it in the Phil. Trans. for 1764, p. 91. Some writers have imagined, that the Latin, Italian, and French words, signifying *crimson*, were more particularly applied to the colour dyed from the coccus polonicus; but I do not find sufficient reason for adopting that opinion.

Very similar to the coccus polonicus is an insect, which in many parts of Europe was formerly collected from the roots of the Burnet, (poterium sangui sorba, Linn.); and which was used, particularly by the Moors,

for dyeing wool and silk of a rose colour. Ray, in describing this plant, says, " Hujus radicis adnascitur quibusdam in locis *granum rubrum*, quo utuntur tinctores ad colorem *carmesinum*, unde sunt qui pro cocco habent, et coccum radicum appellant," &c. Hist. Plantar. 401.

The coccus uvæ ursi, Linn., is another insect of the same order, and very much resembling the coccus polonicus, both in its properties and form, excepting the circumstance of its being nearly twice as large. It affords a crimson dye with alum, but is now seldom employed.

CHAPTER III.

Of the Natural History of Cochineal.

"Our vallies yield not, or but sparing yield
"The dyers' gay materials. Only weld,
"Or root of madder, here, or purple woad,
"By which our naked ancestors obscur'd
"Their hardy limbs, inwrought with mystic forms,
"Like Egypt's obelisks."

DYER.

THE cochineal, or coccus cacti of Linnæus, is arranged among the "Insecta" of the fifth class of that great naturalist; and in the second order, comprehending the "Hemiptera," (half-winged insects, &c.) The body of the male is slender, of a red colour, covered by two wings, spread horizontally, and crossing each other a little on the back, and enabling him to fly, or rather flutter. The head is distinct, but small, with two diverging slender antennæ; the abdomen or tail is terminated by two small and very long diverging hairs; he has six feet, with which he sometimes jumps, like the lacca insect; and hence Linnæus has applied the term "saltatoria," as one of his distinguishing characters. The male insects are but seldom found among the cochineal sent to Europe. The back of the female is hemispherical, and crossed by numerous wrinkles; she is of a dark reddish brown colour; her mouth is a small tubular projection from the thorax; she is without wings, but has six legs; these, however, only serve her to remove during a short interval immediately succeeding her birth; after which they become useless, and ceasing to grow, whilst the body enlarges greatly, they, with the proboscis and antennæ, remain so small as to be afterwards hardly perceptible, at least without a very minute inspection. This circumstance probably occasioned, and certainly confirmed,

the belief which prevailed very generally in Europe, during a considerable number of years, that these insects were vegetable grains or seeds.*

The cochineal is nourished, perhaps exclusively, by some of the different species of the *cactus*, or Indian fig, (called by some of the prickly pear,) a genus of plants, of which twenty-eight several species have been described, all originally found in America only; of very different forms, and producing fruits of various colours when ripe, according to the species on which they respectively grow, as yellow, red, crimson, purple, violet, green, &c. Among these, the red or crimson-coloured fruits more especially contain a mucilaginous juice, which communicates the colour of the fruit in a high degree to the urine of those by whom it is eaten. That species on which the domesticated cochineal has been commonly propagated, is denominated cactus cochenillifer or coccinilifer by Linnæus. But the insects live naturally, in their wild state at least, on some of the other species, particularly the cactus tuna, cactus opuntia, and cactus pereskia; all of which, as well as the cactus cochenillifer, belong to

* Caneparius was deceived in this way. He had been informed, that the cochineal consisted of insects collected from plants of the cactus kind by the help of forceps, and smothered; but he considered this as fabulous, asserting that the cochineal, which he calls "*kabasinii grana*," if steeped in hot water, recovered their *original form*, which, adds he, is not that of any thing animalcular, but distinctly the figure of a seed or grain of some fruit. "Non est ullius animalunculi, at seminis sive grani fructus figuram refert. Quare hæc grana sunt ficus Indicæ rubra et splendida ut sanguis." He had heard that the fruit of the cactus "*Tunæ*," or Indian fig, was red, and that it tinged the urine of those eating it, of a blood colour, which encouraged him to conclude as he did, that cochineal must be the seeds "*ipsius tunæ;*"—"pro colore, *carbisino* vulgo *chremise* conficiendo tinctoribus commodo." See Caneparius, De Atramentis, &c. Venice, 1619. p. 211, 212.

that section of cacti which Linnæus distinguishes as "opuntiæ compressæ, articulis proliferis," *i. e.* flattened or compressed with prolific articulations. The cactus cochenillifer, however, which the Mexican Spaniards call nopal, is alone cultivated for the purpose of feeding and breeding these insects; partly because is is unarmed, or without those offensive spines which beset most of the other species.

The Spaniards, on their first arrival in Mexico, about the year 1518, saw the cochineal employed, (as it appears to have been long before,) by the native inhabitants of that country, in colouring some parts of their habitations, ornaments, &c. and in staining their cotton; and being struck with its beautiful colour, some accounts of it were given to the Spanish ministry, who in the year 1523, (as Herrara informs us) ordered Cortes to take measures for multiplying this valuable commodity;* but as the Spaniards then in America were careless of every thing but gold and silver, they left this to be done by the natives, who, from the large supplies soon after sent to Europe, appear to have successfully employed themselves for that purpose.

It is remarkable, that though Acosta had stated the cochineal to be an insect, as early as 1530, and though

* Herrara does not use the name of cochineal, but that of *grana*, (as other Spanish writers have since done); and he says, (Decade, iii. v. 3.) the Catholic King had been informed that these *grana* were abundant in that part of America, and that the sending them to Spain might furnish means for paying the *contributions*, &c.:—they were probably then supposed to resemble kermes. I have not been able to ascertain the origin of the term cochineal, or coccinilla, nor the time when it was first applied to these insects: perhaps, as they were smaller than the kermes, the term coccinilla was intended as a diminutive of *coccum*, as platina was of Plata, and both employed from similar motives; perhaps, also, it may have been erroneously supposed to belong to the genus coccinilla, or lady-bird.

Herrara and Hernandez did the same afterwards, these opinions were generally overlooked or disregarded, and the people of Europe were for many years induced to believe, that this insect was a vegetable grain or seed, as I lately mentioned; a contrary opinion was, indeed, given by the anonymous author of a paper, in the third volume of the Philosophical Transactions, (printed in the year 1668,) in which he supposes cochineal to be an insect, "*engendered*" by the fruit of the prickly pear; and being a believer of equivocal generation, he proposes to employ fermentation as a means of engendering and multiplying these insects more copiously.

In the year 1672, a paper written by Lister, was published in the seventh volume of the Philosophical Transactions, concerning the kermes, in which he "conjectures cochineal may be a sort of kermes." And the seventeenth volume of the Transactions, published in 1691, contains some observations concerning the making of cochineal according to a relation had from an old Spaniard at Jamaica, who says, "Cochineal is the same which we call lady-bird, alias cow-lady,* which at first appears like a small blister, or little knob upon the leaves of the shrub on which they breed, and which afterwards, by the heat of the sun, becomes a live insect as above, or a small grub."

Early in 1693, Father Plumier wrote and subscribed a declaration, which he delivered to Pomet, affirming cochineal to be an insect living on the opuntia or Indian fig, and that he had seen it in the island of St. Domingo;

* The lady-bird, or cow-lady, has long been distinguished by the generic name of *coccinella;* a fact which may have occasioned several mistakes. It seems to have misled Professor Fischer, when, in 1758, he proposed to propagate the lady-bird or fly, by placing it on the kermes oak, and the perennial knawel, in order to produce cochineal in Europe.

and De Laet had some little time before described it as feeding on the tuna. Pomet, however, misled by the prevailing opinion on this subject, as well as by several letters which about that time were sent to him from St. Domingo by F. Rousseau, adopted the fallacious accounts of this letter-writer, (who promised to send over to France some of the very plants whose seeds, as he asserted, afforded the true cochineal,) and described this drug as the seed of a plant, two or three feet high, bearing pods of a conical form, in which the cochineal grew naturally. (See Hist. Gen. des Drogues, &c.)

But, groundless as this account was in reality, it obtained so much credit, that no longer than four years since, a very eminent dyer of this metropolis seriously told me, that having bought a large parcel of cochineal, he actually found among it one of these conical pods, containing cochineal naturally attached to the inside of the pods.

Lewenhoek, however, by his glasses plainly saw, that the cochineal was an insect with six legs; and in a letter, read at the Royal Society the 21st of March, 1704, and published in the 24th volume of the Transactions, he positively contradicted all those who had represented it as a vegetable grain; and declared that, by dissections, he had invariably found eggs, or animalcula, in the supposed grains, and often to the amount of two hundred in each. He also represents these insects as "not produced from worms," but as "at once bringing forth their like."

About the year 1730, Dr. Rutty, then Secretary of the Royal Society, published a Natural History of Cochineal, (in the 36th volume of the Transactions,) from a work on this subject by Melchior de la Ruuscher, of Amsterdam, who had procured from Antiquera, in New Spain, the depositions of eight persons, who had been

actually employed for many years in the breeding and management of cochineal, and who swore that they were small living animals with "a beak, eyes, feet," &c.; and the originals of these depositions, notarially authenticated, were deposited in the archives of the Royal Society.* Not long after this, Reaumur, in his Hist. des Insectes, and Dr. Brown, in his History of Jamaica, described the female cochineal with sufficient accuracy; as did Linnæus some time after, from some which had been sent to him by Rolander from Surinam, in the year 1756;† though neither of these naturalists had ever seen the male cochineal.

About the beginning of the year 1757, the late John Ellis, Esq. F. R. S., hearing that the cochineal insect bred in great abundance on the cactus opuntia, in South Carolina and Georgia, wrote to Dr. Alexander Garden, of Charleston, South Carolina, for some of the joints of that plant, with the insects thereon, which were accordingly sent the latter end of that year, and laid before the Royal Society. "These specimens (says Mr. Ellis) were full of the nests of this insect, in which it

* These depositions were juridically taken in October, 1725, to decide a wager on this subject, which wager is said to have amounted to the whole fortune of the loser, though the greater part of it was afterwards generously restored, after having been paid. De la Ruuscher's publication was intitled, "Naturlyke historie van de couchenille, beweezen met authentique documenten;" printed at Amsterdam by Hermanus Uytwerf, 1729.

† Rolander had been one of Linnæus's pupils, and having sent to the latter a *cactus*, stocked with the *wild* cochineal insects, (there being no other at Surinam), the plant was brought to Upsal whilst the Professor was delivering a lecture, and when he afterwards inquired for it, the gardener told him, he just cleaned away the *vermin*, which he supposed the cochineal to be, and had planted it. And as none of the insects could be found alive, Linnæus's description must have been made from those which were dead.

appeared in its various states, from the most minute, when it walks about, to the state when it becomes fixed and wrapt up in a fine web, which it spins about itself.

"In order to find out the male fly, (continues he,) I examined all the webs in these specimens, besides a large parcel which the Doctor had sent me picked off from the plants in Carolina, and at last discovered three or four minute dead flies with white wings. These I moistened in weak spirit of wine, and examining them in the microscope, I discovered their bodies to be of a bright red colour, which convinced me of their being the true male insect. To be confirmed in my opinion, I immediately communicated my discovery to Dr. Garden, which I accompanied with an exact microscopical drawing, and desired he would send me some account of their economy, with some male insects of his own collecting; which he did, in the spring of the year 1762, accompanied with the following observations:

"In August 1759, (says Dr. Garden), I catched a male cochineal fly, and examined it in your aquatic microscope. It is seldom a male is met with. I imagine there may be one hundred and fifty or two hundred females for one male. The male is a very active creature, and well made, but slender in comparison of the females, who are much larger and more shapeless, and seemingly lazy, torpid, and inactive. They appear generally so overgrown, that their eyes and mouth are quite sunk in their rugæ or wrinkles; nay, their antennæ and legs are almost covered by them, and are so impeded in their motions from these swellings about the insertions of their legs, that they can scarce move them, much less move themselves.

"The male's head is very distinct from the neck: the neck is much smaller than the head, and much more so than the body. The thorax is elliptical, and something

larger than the head and neck together, and flattish underneath; from the front there arise two antennæ, (much longer than those of the females), which the insect moves every way very briskly. These antennæ are all jointed, and from every joint there come out four short setæ, placed two on each side.

"It has three jointed legs on each side, and moves very briskly and with great speed. From the extremity of the tail, there arise two long setæ or hairs, four or five times the length of the insect. They diverge as they lengthen, are very slender, and of a pure snow-white colour. It has two wings, which take their rise from the back part of their shoulders or thorax, and lie down horizontally, like the wings of the common fly, when the insect is walking. They are oblong, rounded at the extremity, and become suddenly small near the point of insertion. They are much longer than the body, and have two long nerves; one runs from the basis of the wing along the external margin, and arches to meet a slender one that runs along the under and inner edge. They are quite thin, slender, transparent, and of a snowy whiteness. The body of the male is of a lighter red than the body of the female, and not near so large."*

To Dr. Garden's description, Mr. Ellis, in an account of the male and female cochineal insects, accompanied with drawings, &c. (in the fifty-second volume of the Philosophical Transactions,) adds, that the female has a

* Justice to Mr. Catesby, requires me to mention that he had some years before published the following statement in the Introduction to the first volume of his Natural History of Carolina, &c. viz. "In South Carolina grows a kind of Opuntia, which are frequently three or four feet high, from which I have *often picked cochineal* in small quantities. Both plants and insects were much smaller than those of Mexico; but the latter (i. e. the insects) were in colour and appearance the same."

remarkable proboscis, or awl-shaped papilla, arising in the midst of the breast, which Linnæus calls the rostrum, and thinks it the mouth: "if so, (says Mr. Ellis,) besides the office of supplying it with nourishment during the time of its moving about, it is the tube through which the fine double filament proceeds, with which it forms its delicate web, in order to accommodate itself in its torpid state, during its pregnancy, till the young ones creep out of its body, shift for themselves, and form a new generation.

"In this torpid state the legs and antennæ grow no more, but the animal swells up to an enormous size, in proportion to its minute creeping state. The legs, antennæ, and proboscis, are so small with respect to the rest of the body, that they cannot be easily discovered, without very good eyes or magnifying glasses, so that to an indifferent eye it looks full as much like a berry as an animal.

"As soon as the female is delivered of its numerous progeny, it becomes a mere husk and dies; so that great care is taken in Mexico, where it is principally collected, to kill the old ones while big with young, to prevent the young ones escaping into life, and depriving them of that beautiful scarlet dye, so much esteemed by all the world."

I ought to have sooner mentioned that there are two sorts or varieties of cochineal; the best or domesticated, which the Spaniards denominate *grana fina*, or fine grain; and the wild, which they call *grana sylvestra*. The former is nearly twice as large as the latter; probably because its size has been improved by the favourable effects of human care, and of a more copious or suitable nourishment, derived solely from the cactus cochenillifer, during many generations. But it is only from the wild cochineal, living naturally on some of the *opuntiæ*, in

different parts of America, that the descriptions of Brown, Linnæus, and Ellis, were taken. It must also be observed, that the grana sylvestra are not only smaller than the others, but that their bodies are covered by very fine white downy filaments, which they spin to defend themselves against cold, rain, &c. in their wild state; but which adding to their weight, whilst it yields no colour, contributes with other causes to render them less valuable.

In the month of January, 1777, Mons. Thiery de Menonville left Port-au-Prince, in the Island of St. Domingo, for the purpose of procuring some of the living cochineal insects in Mexico, and bringing them away, to be afterwards propagated in the French West India islands: an enterprise, for the expense of which four thousand livres had been allotted by the French government. He proceeded by the Havannah to La Vera Cruz, and was there informed that the finest cochineal insects were produced at Guaxaca, distant about seventy leagues. Pretending ill health, he obtained permission to use the baths of the river Magdalena; but instead of going thither, he proceeded through various difficulties and dangers, as fast as possible, to Guaxaca, where, after making his observations, and obtaining the requisite information, he affected to believe that the cochineal insects were highly useful in composing an ointment for his pretended disorder (the gout), and therefore purchased a quantity of nopals, covered with these insects, of the fine or domestic breed, and putting them into boxes with other plants, for their better concealment, he found means to get them away as botanic trifles, unworthy of notice, notwithstanding the prohibitions by which the Spanish government had endeavoured to hinder their exportation; and being afterwards driven by a violent storm into the bay of Campeachy, he there

found and added to his collection a living cactus, of a species which was capable of nourishing the fine domesticated cochineal; after which, departing for St. Domingo, he arrived safe with his acquisitions, on the 25th of September, (in the same year,) at Port-au-Prince, where he began immediately to form a plantation of nopals, and to take steps for propagating the two sorts or varieties of cochineal, I mean the domesticated or fine, and the sylvestra or wild; which last he found at St. Domingo, soon after his return, living naturally on the cactus pereskia. But unfortunately for this establishment, he died in the year 1780, through disappointment and vexation, at seeing his patriotic endeavours so little assisted, and his services so sparingly rewarded by the government. M. Thiery de Menonville's labours being thus thus terminated, the Royal Society of Arts and Sciences at Cape François, having collected his papers, composed from them a treatise on the cultivation of the nopals, and the breeding of cochineal, &c. of which M. Berthollet has given a short extract in the fifth volume of the Annales de Chimie, together with an account of his own experiments for ascertaining the effects of the grana sylvestra, produced at St. Domingo, compared with those from Mexico, in dyeing.*

From the observations of M. Thiery de Menonville, it appears that there are two varieties of the nopal, or cactus cochenillifer, growing in Mexico, one called the true nopal of the Garden of Mexico, and the other the Castilian nopal, a name given to the last of these varieties on account of its singular beauty. It appears also that the wild cochineal, or grana sylvestra, when reared upon

* The original publication (from which my account was written,) is entitled, "Traité de la Culture du Nopal et de l'Education de la Cochenille," 8vo. printed at Cape François, 1787.

either of these varieties of the nopal, become almost as large as the fine or domesticated sort, and lose the greatest part of those fine downy filaments with which they are naturally covered, and which contribute to render them less valuable than the latter.

But besides the advantage of affording the most suitable nourishment to cochineal, the nopals have another of very great importance, where these insects are to be raised as objects of commerce; which is, that they are not beset with thorns or prickles, like most of the cacti, and particularly the opuntia, tuna, and pereskia, which, by this circumstance, render the insects nourished upon them, almost inaccessible to any who might wish to collect them: whilst the true nopal, and that of Castile, have none but soft inoffensive thorns, and the nourishment which they afford is at the same time so peculiarly well suited to the cochineal, and especially to the fine or domesticated sort, that these last, though they can subsist on some, will prosper on no other species of cactus; and indeed the wild sort, though found naturally upon several other species of opuntia, are at present raised chiefly on the nopals in Mexico. The young insects, whilst contained within the mother, appear to be all connected *one after the other* by an umbilical cord to a common placenta, and in this order they are in due time brought forth as living animals, after breaking the membrane, in which they were at first probably contained as eggs. Being thus brought forth, they remain in a cluster under the mother's belly for two or three days, until disengaged from the umbilical cord; after which the females, for the only time of their lives, exercise their loco-motive faculties, by creeping to proper situations on the plant; and in doing this they are led by a wise instinct, to prefer the undersides of the different branches or articulations, (as being most de-

fended from wind and rain,) where each attaches herself, by inserting her little tubular proboscis or mouth into the bark, and thus remain *fixed* to the end of life. By this insertion the female draws out for her nourishment the *colourless* mucilaginous juice of the nopal, and soon becomes covered with a fine adhesive downy substance. The male acquires a similar covering, but quits it at the end of a month, and in the shape of a little scarlet fly, jumps and flutters about for the purpose of copulation; and having thereby secured a future progeny, he dies almost immediately after. But the female having other duties to perform, outlives the male another month; at the end of which she is ready to bring forth her young, and this is the precise time for gathering those which are not wanted for breeding; which is done by pressing the dull blade of a knife between the under surface of a branch of the nopal, and the clusters of insects attached to it, when the latter, being thereby separated, fall upon cloths previously spread on the ground to receive them; and a sufficient quantity being thus collected, they are dipped (enclosed in a linen cloth or bag) into boiling water, and suffered to remain in it so long as is necessary for killing them, but no longer, lest the water should extract some of their colour. This being done, they are thoroughly dried, by spreading and exposing them to the rays of the sun, by which they shrink so as generally to lose about two-thirds of their former weight. This, which has been found to be the best method of drying the cochineal, is now generally practised, though others were formerly in use; such as ovens, flat baking stones heated, &c.

M. Thiery de Menonville describes the male of the domesticated or fine cochineal as perfectly similar to that of the wild in every respect, excepting its size; nor does there appear to be any considerable difference be-

tween the females of these two varieties. The domesticated female, instead of that downy covering, which enables the wild to bear inclement seasons, is only covered by a fine white powder or farina, serving in some degree as a defence against rain and cold, but not enough to enable her to remain abroad like the wild insects during the rainy seasons, which occur twice in every year. When these approach, the domesticated insects are all gathered and dried, excepting only those intended for breeding a future stock; which are preserved, by either removing the nopals inhabited by them, into situations where they are secured from wind and rain, or by raising frames over them, and covering them with thatch or matting, until the return of favourable weather; but the wild insects, being more hardy, as well as more prolific, when once placed upon the nopals, would not only perpetuate, but multiply themselves, without any farther care, to such a degree as to exhaust and destroy the plants, were they not all collected at the end of every two months, and the plants perfectly cleansed (by wiping them with wetted cloths) from the down and other animal impurities left on their branches. The nopals become fit to nourish the cochineal at the end of eighteen months from the time they were planted. The quantity of fine or domesticated cochineal, which a single nopal can nourish, usually weighs a third more than it could nourish of the wild. These last have also the disadvantage of selling for a much less price; but in return, they are gathered six times in each year, whilst the fine yield but three crops in the same space, their propagation being wholly suspended during the rainy seasons.

In Mexico it is thought necessary to keep the two sorts or varieties of cochineal separated, at the distance of about one hundred perches from each other, lest the males of the wild, by impregnating the females of the

other sort, should occasion a degeneration of the latter; a circumstance which seems to indicate that both sorts originated from the same stock, and that the domesticated is only an amelioration of the wild cochineal, through the favourable effects of a more suitable nourishment, and of warm covering; and this is rendered the more probable, by M. Thiery de Menonville's observation, that the former are never found in the fields or forests of Mexico, nor indeed any where but in the gardens and plantations of those employed in rearing them. But if the present size, appearance, and habits, of the domestic cochineal, were those which naturally belong to the insect, it might be supposed capable of maintaining an independent existence, remote from the dwellings, and without the help of mankind, as it must have done before its properties were so well known as to render it an object of human care and protection; and in that case, some of this sort of cochineal doubtless would have continued to subsist in their natural state, since the whole of a race, composed of so many minute individuals, could not have been taken and brought under the protection and dominion of man. Nor is it easy to explain why none of them ever are found in a wild state, but by supposing them to have been rendered effeminate by luxurious food, and by protection from inclement weather; and that, consequently, they have been enabled to lay aside their natural downy clothing, as sheep lay aside their wool, when, after being removed to warm climates, they find it no longer necessary; and that their natural habits and means of self-preservation being lost, they are rendered incapable of subsisting without a continuance of the same fostering care which first occasioned their effeminacy; or, if they ever do find means to subsist without it, they do so only by regaining their natural downy covering, and by returning again to their

primitive habits, so as not to be any longer distinguishable from those who were never out of the wild state.

After the death of M. Thiery de Menonville, the stock of fine or domesticated cochineal, which he had multiplied in the garden at Port-au-Prince, was suffered to perish by neglect; but the hardier wild sort, having found means to subsist, though neglected, was afterwards taken under the care of M. Bruley, (substitute of the attorney-general of that province,) who from the remains of M. de Menonville's establishment, formed a plantation for propagating and multiplying these insects, of which he sent a considerable quantity, in the year 1787, to the minister of the French marine at Paris, at whose request the Royal Academy of Sciences commissioned M. Berthollet, and three others of its members, to cause proper experiments to be made therewith, which they accordingly did, under their own inspection, at the celebrated establishment of the Gobelins near Paris; and from these experiments it appeared, that the grana sylvestra of St. Domingo afforded colours by dyeing, exactly similar to those of the Spanish fine cochineal, allowing only after the rate of twelve ounces of the former for five of the latter. M. Bruley some time after sent to France a second parcel of the same cochineal, produced from his plantation in the year 1788; and this being tried by the same commissaries of the Royal Academy, though in different ways, produced nearly the same effects.

Very considerable differences of *external* colour or appearance occur in different parcels of the fine cochineal; probably, because the white farinaceous powder, with which these insects are naturally covered, is more or less washed off by the hot water in which they are killed by immersion, as well as by other circumstances which occur in the drying and packing. When this

powder has been entirely removed, the insects appear of a chocolate colour, inclining a little to the purple, and they are then called *renigrida.* Generally, however, so much of the white powder remains, especially in the little furrows which cross the insect's back, as occasions a greyish appearance, called *jaspeada;* and sometimes, indeed, this powder so perfectly covers the cochineal, as to render them all over white. This I remember to have been particularly the case with a parcel which a friend of mine had purchased, and which was refused by several dyers to whom it had been sent, from a persuasion of its having been fraudulently covered by white lead, or some other metallic calx intermixed with it, to increase the weight; and one very eminent dyer alleged, that he had formerly seen and tried a similar parcel, and that the white powder had been found to consist principally of a preparation of mercury. That I might be enabled to ascertain whether an opinion so unlikely had any foundation, my friend caused several ounces of this powder to be separated from the insects by sifting; and having tried it sufficiently, I found it to be entirely of an animal nature, and apparently nothing but the farina which naturally covers these insects. It even yielded a considerable portion of the true cochineal colour, and dyed good scarlets in the usual way, though it probably was assisted by some of the limbs or other parts of the bodies of the insects, separated by rubbing in the sieve: but I am persuaded that a part of the colour in question naturally existed in the farina or white powder itself; and if this be the case, it would be highly advantageous to contrive means for killing the cochineal, without washing off any part of the powder in question, which might, I think, be done by putting them into tinned vessels, made so as to shut closely, which might be plunged into boiling water, and withdrawn at a proper

time, without letting a single drop of water come into contact with the insects, or carrying off any of the powder in question. And perhaps this method might be used with advantage, even if it should be found that no colouring matter resides in the white powder, since it is difficult to conceive that the cochineal can be plunged into boiling water, so as to wash away the powder entirely, (as is frequently done,) without a loss of some part of the colouring matter contained in the bodies of the insects themselves. In general, therefore, it will be safest to choose that cochineal which is large, plump, clean, dry, and of a *silver white* colour on the surface.

The true original grana sylvestra seem to have been very different from the composition which is at present sold under that denomination in this kingdom, and which has the appearance of a dry powder, with many small lumps or fragments of something which had been previously formed into a cake or dried uniform mass. It affords, though in an inferior degree, some of the same sort of colour as cochineal, but in a small proportion; six pounds being necessary, according to my experiments, to dye as much cloth as one pound of the fine cochineal; whereas the true grana sylvestra are represented as yielding at least half as much as the fine, and they sell for at least half the price in some parts of Europe, whilst here the substance so called, and which has not the least appearance of any insect, sells at present for less than an eighth of the price of fine cochineal. Probably it is composed of the white downy substance which the wild insects are represented as leaving in great abundance on the nopals, and of other excrementitious matters deposited by them, joined to fragments, broken limbs, and dust, of the insects themselves, and perhaps with an addition of some vegetable matters, all beat up into one uniform mass. Something of this sort

was formerly practised even with the true cochineal, according to Dr. Brown, who says, "The cochineal insects used to be prepared by pounding them, and steeping the pulp in the decoction of the texuatla, (a species of melastoma, as he supposes,) or that of some other plants, which they observed to heighten the colour. This (continues Dr. Brown) was left to settle at leisure, and afterwards made into cakes and dried for the market." Hernandez also mentions that in his time *cakes* were made from cochineal in Mexico. Probably the true grana sylvestra, mixed with fragments of the true cochineal, compose what is sold in this country under the name of granillo, which appears, as the name indeed imports, to consist chiefly of insects somewhat smaller than those composing the fine cochineal, and therefore, in that respect, answers to the best authenticated descriptions of the wild cochineal.

It had been generally believed that the cochineal derived its colour from the red or crimson fruit of the nopals, and other species of opuntiæ; and I was formerly induced by this opinion to make various trials with the red fruit of the cactus opuntia for dyeing, instead of cochineal. They all, indeed, proved unsuccessful; but I was disposed to attribute my failure to the want of that kind of animalization, which the vegetable red colouring matter was supposed to receive, when eaten and assimilated by the insect: and I thought it probable, that other vegetable colouring matters might be equally improved in the same way, and that perhaps, instead of insects, it might be advantageous to employ larger animals for this purpose.* It is, however, now

* Dr. Garden relates, that a negro woman in South Carolina, who then gave suck, having eaten six of the red fruit of the prickly pear, (cactus opuntia), and some of her milk being collected, and left until the cream had separated, this last was found to be of a

certain, from the observations of M. Thiery de Menonville, and from other well-attested relations, that the cochineal insects *do not feed on the red fruit* of the cactus, but upon its branches or articulations, to which they adhere, and which *contain nothing like a red juice;* and that they sometimes live, propagate, and preserve their colour on those species of cactus which *do not bear red-coloured fruits:* consequently, the colour of these insects does not result from that of their food, but from their peculiar constitution and organization.*

reddish colour, considerably weaker, indeed, than the lively red which the urine was found to acquire by the same fruit. See Philosoph. Trans. vol. 50, p. 269. In the third volume of the same Transactions, mention is made of a berry growing in Bermudas, and called the "Summer Island Redweed, which berry is as red as the prickly pear, and giving much the like tincture; out of which berry cometh out first worms, which afterwards turn into flies, (somewhat bigger than the cochineal fly,) feeding on the same berry, in which there hath been found a colour no whit inferior to the cochineal fly."

* Although the facts here stated were published more than eighteen years ago, the error which they were intended to correct, not only subsists, but continues to be propagated by weighty authorities. M. Fabroni, who was lately mentioned at p. 214, asserts, (Ann. de Chimie, tom. xxv. p. 301) that the cochineal insect can with its proboscis extract from the nopal its juice, which afterwards communicates its fine red colour to the insect; and this juice, he adds, "selon moi, est le même que la nature nous présente à *nu* dans les *fruits mûrs* de cette même plante."

Bouillon La Grange also endeavours to maintain the same error, in his Manuel de Chimie, tom. ii. p. 743, where he asserts that the cactus coccinillifer "communique son *suc rouge* à l'insecte, qui s'en nourit." But a more important support has been given to this error by the author of a respectable botanical work, now publishing in Jamaica, under the title of Hortus Jamaicensis, in two volumes 4to.; who not only adopts the error, but, to confirm it, has (vol. i. p. 412) adduced copious extracts from Mr. Long's History of Jamaica, (a work in great estimation,) of which extracts the following are a part, viz. "This juice (of the fruit of the cactus) is the natu-

The very great demand for cochineal, almost immediately after it had been made known in Europe, caused a very rapid multiplication thereof in the Spanish Ame-

ral food of the cochineal insect, which owes to it the value and property it possesses as a dye in some of our principal manufactures. The exuvia and animal salts of the insect are, from the minuteness of its parts, inseparable from the essential principles of the dye; whence it follows, that such a heterogeneous mixture must necessarily destroy the brilliancy of colour inherent to the juice of this fruit; and that the juice itself, which alone contains the dyeing principle, must, if unmixed and brought to consistence, yield a true perfect colour, lively and brilliant, as we find it in its natural state."

"Upon this hypothesis, Mr. David Riz, an ingenious gentleman of Kingston, in this island, proceeded in several experiments to obtain from the plant artificially, what nature accomplished in the insect, and at length happily succeeded, by inspissating the juice; but the means he used are not yet communicated to the public. Encouraged by this discovery, he went to England with seventy-six processes, differently manufactured, to try which would answer best as a substitute to the cochineal. After a great number of experiments, he found one process which communicated a crimson colour to silk and wool, superior to that given by cochineal; trials of which were made before a number of the principal dyers in and about London, at the *Museum of the Royal Society*, invited there for that purpose. He also found two other processes, which promised, with very little alteration in their manufactory, to afford the colour-making dyes of scarlet and purple. Upon a moderate calculation it was found, that his colour would go further than *three* times the quantity of cochineal, which he accounted for by remarking that there is a great part of the insect, as its skin, &c. which affords no dye, but that the whole of his process was genuine colour, with little or no impurity."

"Notwithstanding the advantages that might be derived to the nation from this gentleman's discovery, he met upon the whole with very little encouragement to prosecute his manufacture further." Long's History, &c. p. 731.

Upon this statement I shall only observe, that if, in fact, Mr. Riz did, as is alleged, produce any substance or preparation capable of dyeing a good scarlet, and of producing as much colour as three times its weight of cochineal, he must have obtained it otherwise

rican settlements. It appears from Acosta's statement, that so early as the year 1587, there came to Spain, by a single flota, no less than 5670 arobas of fine cochineal, which, at the rate of 25lbs. each, weighed 141,750lbs.; and the common annual importation, as stated some years since by the Abbé Raynal, has amounted to 4000 quintals, or 400,000lbs. weight of the fine cochineal, 300 quintals of the grana sylvestra, 200 ditto of granillo, and 100 of cochineal dust, which were computed to have sold for a sum equivalent to about nine millions of French livres; without reckoning considerable quantities sent directly from America to the Philippine islands, for supplying a considerable part of Asia. The European importations have, however, been considerably increased, during several of the last years.* Since,

than from the cactus, and probably it must have been an extract of cochineal, like those preparations commonly sold under the name of *carmine*, except that it may have contained none of the aluminous basis, or that of tin. For what purpose such an imposition was practised, I am not bound to inquire. But certainly the *red* fruit of any and every species of cactus, is as incapable, *as a cranberry*, of affording a colouring matter similar to that of cochineal; and since it has become notorious that this insect does not meddle with the fruit, (the only part of the cactus which exhibits a red colour) the notion which I now combat, has been left without any foundation or probability. I have already stated that the colouring matter of the kermes, is similar to that of cochineal, and yet nobody has ever suspected the kermes to derive its colour from the leaves of the oak, on which it is produced, there being no *red* juice in these leaves, nor indeed, in those parts of the cactus to which the cochineal insects *attach* themselves *exclusively*. An error similar to the preceding, seems to have subsisted formerly in regard to the *purple-giving murex*, as mentioned by Aristotle (Hist. Animal. vi. cap. Ed. Scaliger,) who says that a sea-weed (Fucus) probably Orchella, having been cast on shore near the Hellespont, which yielded a purple colour, the neighbouring inhabitants concluded it to be the *food* of the purple shell-fish.

* This was written in 1793.

according to very good information, which I have received, the quantities of fine cochineal brought to Spain in the years 1788, 1789, and 1790, amounted to eleven thousand bags, weighing 200lbs. each, and making together 2,200,000lbs. weight; and between the first of January 1791, and the first of October in the same year, the importations had exceeded 2000 bags.

It must, however, be observed, that the importations during these years were somewhat greater than usual, because an advance in the price of cochineal in Europe had induced the holders of it in America to send their stocks more speedily to market, in order to avail themselves of the higher prices; and, from accurate calculations, I think it may be concluded, that the average quantity of fine cochineal annually consumed in Europe amounts to about three thousand bags, or 600,000lbs. weight, of which about 1200 bags, or 240,000lbs. weight, may be considered as the present annual consumption of Great Britain. A greater quantity comes indeed into the kingdom, but the surplus is again exported to other countries. These 1200 bags may be supposed to cost 180,000*l.* sterling, valued at 15*s.* per lb. which has been about the average price for some years past.* According to Don Antonio Ulloa, the greatest quantities of cochineal are produced at Oaxaca, Tlascala, Chulula, Neuva Gallicia, and Chiapa, in New Spain, and at Hambatio, Loja, and Tucuman, in Peru.

About six years ago, Dr. James Anderson, physician-general on the company's establishment at Madras, persuaded himself that he had found the true cochineal in-

* Since the year 1793, the price of cochineal has more than doubled; it has continued during the last eight years at more than 30*s.* the pound, and has sometimes exceeded 50*s.* But this augmentation of price, or a change of fashion, seems to have considerably diminished the annual consumption of Great Britain, which may now be estimated at about 750 bags.

sects subsisting naturally on a species of salt grass in that part of India; and some parcels of a dried insect, probably of the coccus kind, (but more like the kermes,) which he mistook for the true coccus cacti, were sent by him to this country; of which I made several trials, at the request of a friend, (as others also did,) and found them to be neither of the same species, nor possessed in any degree of that particular colouring matter for which the cochineal insect is so highly valued; though in their dried state they had nearly the same external appearance, excepting their size, which was considerably less than that of the true Mexican cochineal; but upon rubbing them in a mortar, I soon perceived, that instead of breaking into a dry powder like cochineal, they could only be beat into a kind of unctuous paste; nor would any degree of drying, short of combustion, overcome this unctuous quality, or render them capable of being rubbed into the form of a powder; and in point of colour there was a more essential difference, since they produced nothing better than a chocolate brown, by the means usually employed for dyeing scarlet with cochineal, nor indeed by any other means. This chocolate colour proved indeed sufficiently durable on wool; but it may be dyed so cheaply by other matters, and indeed these insects yielded so little of it, that they never can be worth collecting as a dyeing drug.*

It occurred to me, however, on this occasion, that though Dr. Anderson had failed in his expectation of

* The Company, in their letter of the 31st of July, 1787, to the government of Madras, were pleased, from very laudable motives, to direct, that every further pursuit respecting this species of insects, "should be effectually discouraged," because, "were it to fall into the hands of improper persons, it might be made use of to mix with and adulterate the real cochineal, to the great injury of the consumer, as it would most assuredly spoil the beauty of every scarlet done therewith."

finding the cochineal in a country where it probably never existed, (the genus of plants on which it is naturally fitted and destined to live having been originally produced only in America,) yet it would not be very difficult to convey both the insects, and the cactus cochenillifer (their natural food and habitation) to the East Indies, and there propagate both, so as in a few years to obtain from thence ample supplies of a drug so highly important in a great manufacturing country, and for which nearly 200,000*l.* sterling are annually paid by this to the Spanish nation, especially as great advantages in this respect would result from the cheapness of labour and subsistence in the East Indies; and considering moreover how much the quality of the indigo of that country had been improved, and the quantity increased within a few years, through the measures taken so opportunely for these purposes by the East-India Company, at a time when the usual supplies of that article from other countries had been greatly diminished.

Similar ideas on this subject occurred, or were suggested, to the Directors of the East-India Company, who, in the spring of the year 1788, procured from his Majesty's botanic garden at Kew (through Sir J. Banks, Bart. P. R. S.), some of the *true nopal plants*, two of which were sent out by the Bridgwater, during that season, to Madras, and put under the care of Dr. Anderson, where they have since been multiplied to several thousands,* and been transplanted from thence to Bengal, and St. Helena, in order that a sufficient stock might be in readiness to receive any cochineal insects which should arrive; a committee of the Directors hav-

* It has since been ascertained that these plants were not the true *nopal*, or cactus coccinillifer, but a different species, much less suited to the purpose for which they were intended.

ing previously reported as "their opinion, that it be recommended to the Committee of Correspondence to take such measures as they shall judge best suited for procuring from America a quantity of the cochineal insect, with a view to the introduction of the same upon the coast of Coromandel." Unfortunately, however, it does not appear that any measures have yet been effectual in procuring the domesticated insect, or even the sylvestra, though this last exists in Jamaica, (as does the true nopal*) and in many other accessible parts of America, and probably in more than ordinary perfection in Brasil; at least I made trial about the year 1787 of some which had been sent from thence by the way of Lisbon, and which yielded *full* as much colour, and of as much beauty, as half its weight of the *very best fine cochineal;* and until this last can be obtained, would it not be advisable to make trial of the other, which, by being properly nursed, and nourished upon the true nopals, might perhaps, in a little time, improve so as to supersede the necessity of seeking any farther?†

* The cactus coccinillifer, and the cactus Pereskia (or Spanish gooseberry), are both mentioned in a recent catalogue of the *Hortus Eastensis*, as growing in the botanical garden of the late Mr. East, at Jamaica; and others are said to be growing in Longville Garden, in the same island.

† Subsequently to this suggestion, and as I believe in consequence of it, some of the Brasilian cochineal insects were carried to India by one of the Company's ships which had touched at that part of America, and some quantities of cochineal have been at different times imported to this country, which were derived from the Brasilian *stock*. I had collected authentic and valuable information on this subject, and had made experiments with the cochineal itself; but the papers containing an account of them, and of the information so collected, have been unaccountably lost or purloined, with others, probably of more importance, and I dare not rely on my recollections so far as to enter upon any statement of their contents.

CHAPTER IV.

Of the Properties and Uses of Cochineal; with an account of new Observations and Experiments calculated to improve the Scarlet Dye.

"Le travail a été mien, le profit en soit au lecteur."

JEAN REY.

IN the English translation of Clavigero's History of Mexico, the ancient inhabitants of that country are said to have obtained a *purple* colour from cochineal. Probably, however, either the author or translator of that work, has mistaken purple for crimson; this last being the *natural* colour of cochineal, and what it always affords with the aluminous basis, which Clavigero, in another part of his history, says the Mexicans had been used to employ in early times; though it certainly is difficult to understand how they could have become acquainted with it. This account moreover accords with that of Herrara, who, after mentioning the Tuna or Nopal of Tlaxcalla, says, "Optimum longè granum dat Tlaxcallum cujus indigenæ prestantissimam tincturam ex illo conficiunt, hoc modo, comminuunt et macerant in decocto *aluminis*, et ubi resederit, cogunt in tabellas, quas Hispani vocant *grana en pan*."*

There is also reason to conclude, that during a number of years, none but the aluminous basis was used for dyeing with cochineal in Europe,† until the accidental falling of a solution of tin by aqua-fortis, into a decoction of co-

* Whilst alum was the only mordant employed with cochineal, these *grain cakes* made with a decoction of alum might answer very well, but not afterwards.

† Caneparius (de Atramentis, p. 191), mentions the dye "ex granis ficus Indicæ Mexicani, quæ prout semina sunt, eisque tinctores pro *carbisino* colore utuntur." Hence it appears that cochineal

chineal, about the year 1630, manifested the singular power of the oxide of that metal in *exalting* the colour of this drug, and led to a discovery of that most *vivid* of all colours, the *cochineal scarlet*. Kunckel and others state this accident to have happened to a German, named *Kuster* or *Kuffler*. But others, and particularly Beckman, assert that it occurred to a Dutch chemist, Cornelius Drebbel, who was born at Alkmaar, and died at London in 1634,* and that he communicated this occurrence to Kuffler, who was an excellent dyer at Leyden, and afterwards became the son-in-law of Drebbel.† That Kuffler put the discovery into practice in his dye-house, and that the scarlet was thence first named Kuffler's colour, and after-

was then (1619) only used for dyeing crimson, at Venice, where the art of dyeing had long been most successfully practised.

* If it be true that Drebbel died in London in 1634, he had probably come to England to derive some benefit from his discovery, and died before he had time to do so.

† Mr. Macquer, in a memoir printed among those of the Academy of Sciences at Paris for 1768, says, "Drebbel, chimiste Hollandois, a imaginé d'employer dans la teinture de cochenille, de la dissolution d'étain faite par l'eau régale, et dès lors on a obtenu le plus vif et le plus éclatant de tous les rouges dont l'art, et même la nature ~~nous~~ ait donné l'idée; je veux dire l'écarlate couleur de feu, qui a porté d'abord le nom d'*escarlate de Hollande*, parce que c'est dans ce pays que les premières manufactures ont été établies," &c.

Mr. Macquer seems to have been mistaken in supposing that the first solutions of tin employed in this way were nitro-muriatic, or made with aqua-regia, there being very good reason to believe, that aqua-fortis alone, though perhaps impure, was used for some years for this purpose.

Mr. Delaval, without the smallest probability, attempts to carry the first use of tin for dyeing back to very remote antiquity; and thinks the Phœnicians used that which they were said to have brought from Britain in this way, because (as he erroneously asserts) "this is necessary to the production of red colours, whether from animal or vegetable materials." See Experimental Enquiry, &c.

wards scarlet of Holland, or Dutch. From him a Flemish painter, Kloeck or Gluck, learned the secret, and communicated it to one of the famous Gobelins at Paris; and another Fleming, named Kepler, brought the secret to England about the year 1643, and the first dye-house for dyeing the new scarlet having been soon after established at *Bow*, near London, that colour was for some years called the *Bow* dye.

It has been generally supposed, that after the effects of tin upon the cochineal colour had been discovered, as before mentioned, nothing more was wanting to produce what is at present called scarlet, than to apply the colour so produced as a dye to wool; or in other words, that a nitric, or nitro-muriatic solution of tin, was sufficient to change the natural crimson of cochineal to a scarlet. Such at least has been the opinion of every writer on the subject until the present hour; though it will hereafter be proved to have been an erroneous opinion, and that the nitric solution of tin invariably produces (with cochineal) a crimson or rose colour, and not a scarlet, unless other means be also employed to incline the cochineal colour, so far as may be necessary, towards the *yellow;* and the means of doing this seem to have been stumbled upon, and continually employed without any knowledge of their true effect. I have already mentioned that tartar is, and for many ages appears to have been, generally employed with alum, to compose the ordinary boiling liquor or mordant for woollen cloths: and it seems probable, that when the first attempts were made to employ the solution of tin, instead of alum, it would naturally have been imagined, that as tartar had been found useful with the latter, it must also produce good effects with the former, and that a trial of it having been thus produced, and the most brilliant of all colours having been found to result from this combination of tartar with the solution of tin, their

joint use was afterwards continued, without any inquiry concerning the particular share which either of them had in producing such pleasing effects.

At first indeed a diluted nitric acid appears to have been employed for dissolving the tin without any admixture of the muriatic;* but as the former would have held but a small portion of the calx of that metal in a state of suspension, and as even that portion would have been liable to precipitate in a few days, the practice of adding either a little muriate of ammonia, or a little sea-salt, to the aqua-fortis, and of thereby producing an aqua-regia, or nitro-muriatic acid, seems to have been introduced, though it did not become general until a considerable time after; since Hellot gives an account of the process used in his time for dyeing scarlet at Carcassonne, in which tin was dissolved *only* by diluted aqua-fortis; and he mentions M. Baron, as claiming the merit of having been the first in that city who employed an aqua-regia for dissolving tin, *in order to prevent a precipitation of its calx or oxide;* and even when this was done, the muriate of ammonia and sea-salt were added, but very sparingly, from a belief, which still subsists universally, that a more liberal use of either of them in this way, or of the muriatic acid in their stead, would render the cochineal colour a crimson instead of the scarlet, which last is supposed to be a peculiar production of the nitrate of tin,† though nothing can be more groundless than this belief; since the nitrate, and the muriate of tin, both *equally* afford a crimson

* Doubtless the aqua-fortis was then impure, by containing at least a small proportion of the muriatic acid, as it commonly does at this time.

† I give this denomination to solutions of tin produced solely by a diluted nitric acid, without regarding the decomposition, more or less complete, which the acid undergoes in consequence of such solution.

colour with cochineal, and neither affords a scarlet without the aid of other means.

The dyer's ordinary solution of tin is made with that species of diluted nitric acid, called single aqua-fortis, and which, as usually prepared, is capable of dissolving about one-eighth of its weight of tin, grained or granulated, by pouring it, when melted, into water, briskly agitated with a bundle of rods, or by other suitable means.

For each pound of aqua-fortis, it is usual to add after the rate of one or at most two ounces of sea-salt, though some prefer, and probably with reason, the muriate of ammonia for this purpose. About half as much water as of aqua-fortis, is moreover commonly added, in order still farther to dilute the acid, and moderate its action on the tin. Those solutions of it which are made most slowly, and with the least separation of fumes or vapours, have been found to succeed the best; probably, because in these the tin is less calcined, or oxygenated, and the solution retains a larger portion of azote, or nitrogene, than in those which proceed more rapidly. It is usual to allot after the rate of two ounces of grained tin to every pound of aqua-fortis; and the metal is put into it, at different times, waiting until one part is nearly dissolved, before another is added, lest too much heat should be evolved, and the solution proceed too rapidly; though there is no danger of this, in the latter part of the process, which indeed should be protracted so as to last two or three days. The water mixed with the aqua-fortis should be ascertained by weighing or measuring, in order that a proper allowance may be made for it in calculating the strength of the solution, or the weight of metal contained in a given quantity thereof, which, supposing half as much water as of aqua-fortis to have been used, will be about one-fourteenth part of the whole; and when the solution (which the dyers in this country generally call *spirit*) has been made

in these proportions, from eighteen to twenty five pounds of it are commonly employed to dye a full cochineal scarlet, upon one hundred pounds weight of woollen cloth; and of this quantity three-fifths, or two-thirds, are usually employed in the first preparation, or boiling part of the process; for which supposing one hundred pounds weight of cloth are intended to be dyed, about eight pounds of crude tartar or argol are put into a suitable dyeing kettle or vessel, (of pure block tin,) with a sufficient quantity of clean soft water,* and six or eight ounces of powdered cochineal. Immediately after this twelve or fourteen pounds of the solution of tin, prepared as before mentioned, are to be added, and when the mixture is nearly ready to boil, the cloth, being first thoroughly moistened, (that the dye may penetrate and apply itself equally thereto,) is put into the dyeing liquor, and turned through it (by the winch) very quickly at first, and afterwards more slowly, whilst the liquor continues to boil, for the space of an hour and a half or more, after which it is to be taken out, and rinced in clean water. By the *first boiling* or preparation, the cloth will have acquired a flesh colour. For the *second*, or dyeing process, a tin vessel is filled with clean water, and when this appears almost ready to boil, five, or if a *full* colour be wanted, five and one half pounds of cochineal in powder are to be put into it, and well mixed, by stirring for a few minutes; after which, the remaining part of the solution of tin is to be added, and the whole being well stirred, the cloth is to be put into the liquor, and turned *very briskly* through it, over the winch, for a little time, in order that both ends may receive an equal portion of the dye; after which it may be turned more slowly for the space

* Hard water tends to produce a rose colour, which the dyers commonly endeavour to obviate, by boiling bran or starch in their water.

of half an hour, or until the dyeing liquor becomes exhausted, when the cloth is to be taken out, aired, and rinced.

An ounce of fine cochineal is generally deemed necessary for dyeing a pound of cloth; but something less than this portion is frequently made to answer, especially for coarser cloths.*

It is not, however, necessary to follow this (which is the usual) process for dyeing scarlet. I have often given that colour very well at one single though protracted boiling, by mixing the whole quantity of tartar, and solution of tin, and adding the cochineal, after the cloth has boiled ten or fifteen minutes; for such, in this case, is the attraction of wool for the colouring matter, as well as for the oxide of tin, that it will take up both very freely, and retain them permanently, when thus mixed. I think, however, that in this way the cloth may be liable to imbibe both the mordant and the colour, with some inequalities, by reason of the differences which are found to subsist not only in the wool of different sheep, but even of the same individual, when taken from different parts of the body, as was noticed at p. 63; and that it will therefore, always be safest to employ a *previous* boiling, in the manner commonly practised, to overcome the effect of these inequalities, by forcing a sufficient quantity of the mordant or basis, into the pores even of those sorts of wool which are the least disposed to receive it. This boiling may, however, be shortened to a *single*

* Hellot directs an ounce of cochineal for each pound of fine cloth. Berthollet prescribes six pounds of cochineal for every 100lbs. of cloth. Mr. Hawker, a very eminent scarlet dyer in Gloucestershire, assured me, that for fine cloths he commonly employed four pounds of cochineal for every 60lbs. of cloth; but that for coarse cloths he seldom exceeded two pounds and three quarters for that quantity of cloth.

hour, when it is performed with what the dyers call a *seasoned float*, meaning the bath or preparation liquor, which, after having been employed for the same purpose, is replenished according to the ordinary practice, with a fresh portion of the mordant, &c. and thus rendered more efficacious than the *first*.

I have moreover often dyed very beautiful scarlets, by preparing or boiling the cloth with the *whole* quantity of solution of tin and tartar at once, (as is commonly done with alum and tartar,) and afterwards dyeing it unrinced, with the whole of the cochineal in clean water only; and in this way I have found the colouring particles so completely taken up by the cloth, that the liquor became as clear as the purest water, and the colour was generally very perfect.

Most dyers, besides the tartar used in the first boiling, employ half as much of it as of cochineal in the second, or dyeing part of the process; and certainly the doing so will be advantageous, whenever the colour is wanted to approach nearer than ordinary to the orange tint, though this is not the effect which would be generally expected to result from thence. Pœrner uses no cochineal in the first boiling, nor indeed is any necessary, though a little may probably help to decompose the oxide of tin, and fix it more copiously in the fibres of the cloth. For scarlet, many dyers prefer the *red* argol or crude red tartar; but the matter to which it owes this colour is wholly incapable of adding any colour to that which the wool might otherways acquire, and therefore at best its redness will prove useless. Wool is seldom dyed scarlet, until it has been spun, wove, and fulled; because the yellowish tendency which the cochineal colour acquires from tartar in the dyeing process, is nearly all taken away in the fulling, and a *rose* produced instead of a scarlet colour.

M. Berthollet thinks the solution of tin, before described, does not affect the cochineal colours, *merely* by the proportion of that metal which it contains; and that when either sal-ammoniac, saltpetre, or common salt, enter the composition of an aqua-regia, the compound will be less acid than when it consists of the nitric and muriatic acids solely; and that the former deserves therefore to be preferred, as having a less violent action upon the fibres of woollen cloths, and upon colouring matters.

It is remarkable, that during the present century, no considerable improvement has been made in the process or means of dyeing scarlet; a circumstance which is the more extraordinary, since the pre-eminent lustre, as well as the costly nature of this dye, have rendered it an object of particular attention, not only to dyers, but to eminent chemists, by whose researches we might have expected, that at least every obvious improvement therein would have been long since attained. That this, however, has not been done, will, I think, manifestly appear, by the following statement of my own particular observations and experiments on this subject, which began in the year 1786. Having then been led to pour boiling water repeatedly upon powdered cochineal in a china bason, and to decant it as often from the subsiding insoluble parts, until they would yield no more colour, I found that by adding a little potash, or soda, to this seemingly exhausted sediment, and pouring fresh boiling water thereon, a farther copious extraction of colour instantly displayed itself, equal, as far as I could judge, to about one-eighth of the whole of that which had been originally contained in the powdered insects; and having by repeated trials, constantly found this effect, I too hastily concluded, that the colour thus obtained by the help of potash, was so far of a resinous nature, or so intermixed with a resinous matter, as to have always been inca-

pable of being extracted by the means usually employed for dyeing with cochineal; and that if it should be found capable of yielding colours as beautiful and permanent as those dyed with the more soluble colouring particles of these insects, an acquisition might be made of so much *new* colouring matter, which till then had, as I conceived, been always thrown away. That it was capable of yielding such colours, I soon ascertained, by repeatedly extracting this particular colouring matter by the help of potash, and afterwards dyeing small pieces of cloth with it, (in the ways usually employed for dyeing scarlet), and by comparing and exposing them to the weather, with other pieces dyed from the more soluble colouring matter of cochineal.

Continuing my inquiries on this subject, I soon perceived that the colour, denominated scarlet, must in fact be a compound colour, (like green, purple, and orange), consisting probably of about three-fourths of a most lively pure crimson or rose colour, and about one-fourth of a pure bright yellow; and that therefore, when the natural crimson of the cochineal is made scarlet by the means always hitherto employed for dyeing that colour, there must be a *change* produced, equivalent to a conversion of one-fourth of the cochineal colouring matter from its natural crimson to the yellow colour; and as a better yellow might be obtained from other drugs, where it naturally exists, and for a fiftieth part of what it costs when obtained in this way, from the *most costly of all dyeing drugs*, (cochineal), it necessarily followed, that this, the universal and only known method of producing a scarlet, must be highly injudicious, because unnecessarily expensive.

Convinced of this important truth, and at the same time believing too easily, on the authority of Hellot, Macquer, and others, that the natural crimson of cochineal was

rendered scarlet only by the nitric acid employed to dissolve the tin used in dyeing that colour, I began a series of experiments for producing it, without any such *waste* of the cochineal colouring matter. For this purpose it seemed necessary to discover a mordant or basis, capable of permanently fixing and strongly reflecting the pure vivid cochineal crimson, or rose colour, without making it incline to the yellow. I concluded, and found by experiments, that the necessary *purity* and *vivacity* of colour could not be obtained from an aluminous basis, however dissolved, though it doubtless fixes the colouring particles of cochineal more durably than any other mordant; and the like defect was found to accompany the solutions of all the other earths, as well as of the metals, tin alone excepted; and with this farther disadvantage, that most of them either degraded or altered the natural colour of cochineal very considerably. It followed, therefore, that a basis to suit my purpose must be sought for in the pure white calx or oxide of tin, so dissolved or combined, as to reflect the cochineal crimson unchanged, and with the greatest possible lustre. Misled by what those eminent writers Dufay, Hellot, Macquer, Scheffer, &c. had advanced, as well as by the opinions of others, with whom I had conversed on this subject, I erroneously concluded, that all solutions of tin, in which the nitric acid predominated, would necessarily incline the cochineal crimson towards the yellowish tint, and that therefore such solutions ought to be excluded from my experiments. In this persuasion, I dissolved parcels of that metal in almost every other acid, and tried them separately for dyeing with cochineal. Their several effects will hereafter be more particularly stated: at present I need only mention, that of all others the muriatic solution seemed the best suited to answer my purpose, as it both fixed and reflected the pure crimson or rose colour of

the cochineal unchanged,* and with the utmost brightness. To produce a scarlet, therefore, it was only necessary to superadd, and intimately combine with this crimson or rose colour, a suitable portion of a lively golden yellow, capable of being properly fixed and reflected by the same basis. Such a yellow I had previously discovered in the *quercitron* bark, (which will be the subject of a future chapter,) and also in what is improperly called young fustic, (Rhus Cotinus, Linn.) though its colour was less bright, and less durable, than that of the quercitron bark. This last had also the advantage of being not only the brightest, but the cheapest of all yellows, since one pound of the bark in powder, which cost but three pence farthing, dyed, with a sufficient quantity of muriate of tin, between thirty and forty pounds weight of woollen cloth of a full bright golden yellow; and this being afterwards dyed in the same liquor, with one-fourth less of cochineal than what is usually employed, acquired a scarlet equal in beauty and durability to any which is usually given by the ordinary means, with a full proportion of cochineal; and such were the general results of a great number of experiments.

The quantity of muriatic solution of tin necessary to dye a given quantity of scarlet in this way, seemed to me at that time to depend on the proportion of metal contained in it, and this last to depend on the strength of the acid used for this purpose.† That which I employ-

* It must be observed, that when in this and other places I mention the crimson colour as produced by cochineal upon a tin basis, I mean a colour much more lively and beautiful than the crimson dyed from cochineal upon an aluminous basis. The former might, perhaps, with more propriety, be denominated a *rose* colour.

† I have since ascertained, by decisive experiments, that muriatic acid, which has *only* dissolved *one-half* of the portion of tin

ed, and which I bought at the price of 38*s.* per 112lbs. or about four-pence per pound, dissolved in a strong sand-heat, one-third of its weight of granulated tin; and this solution would, with the proportions of cochineal and bark before mentioned, dye about ten times its weight of cloth of a good scarlet colour.

I have said that three pounds of muriatic acid, which cost but one shilling, might be made to dissolve a pound of tin, which would require eight pounds of single aqua-fortis to dissolve it; and this quantity of aqua-fortis, at at the rate of 8*d.* per lb. would cost 5*s.* 4*d.*, so that on each pound of tin dissolved by muriatic acid, instead of the nitric, I calculated a saving of 4*s.* 4*d.* The muriatic acid, therefore, which M. Beaumé had styled the true dissolvent of tin, ("le vrai dissolvant de l'Etain,") seemed also to be of all others the cheapest; and with this further advantage, that a solution made by it was as transparent and colourless as the purest water, and capable of being preserved for many years, in vessels closely stopped, without the least alteration, while the dyers' nitro-muriatic solution of tin or spirit becomes turbid or gelatinous very speedily, and even in a very few days, if the weather be warm.

I may add also, that the muriatic solution of tin seemed to exalt the colours both of the quercitron bark and of cochineal, more than any other.

I perceived, moreover, another advantage resulting from this new method of dyeing scarlet, by a saving of all the tartar employed in the old. Before I began my experiments on this subject, I had endeavoured to learn

which it may be made to dissolve, will go as far as an equal quantity of acid which has been saturated with the metal, and that the effects of the former are in every other respect better than those of the saturated solution, so that this last is at best an useless expenditure of one-half of the tin which it contains.

the purpose which tartar was intended to answer in the usual process for dyeing scarlet; but having obtained no satisfactory answer on this point, I doubted of its producing any good effect, and therefore omitted it in my first trials; and as they succeeded, I also omitted it in all the others.

By these facts and ideas I was led to believe that I had made discoveries likely to produce very important national benefits: and I particularly calculated in the first instance a gain of about $12\frac{1}{2}$ per cent. upon the whole quantity of cochineal consumed in Great Britain, by that part of its colouring matter, which I proposed to extract by the help of potash, or soda, and which I supposed to have been before always lost.

Besides this, I computed that a saving of 25 per cent. upon all the cochineal used in Great Britain for dyeing scarlet, aurora, and orange colours, would result from my plan of obtaining from the quercitron bark so much yellow as was required for the composition of those colours with the cochineal crimson, instead of converting any part of this last more costly colour into a yellow. And, lastly, I calculated other savings, equal at least to 20,000*l.* annually, in the article of tartar, (acidulated tartrite of potash,) and in what the muriatic solution of tin was likely to cost less than that which is commonly used for the purposes in question.

With this opinion of the importance of my discoveries on this subject, I gave an account of them, as well as of an improvement in the black dye, (which will be hereafter explained,) to the right honourable the lords of the committee of his majesty's privy council, appointed for the consideration of all matters of trade, &c. (of which committee the late earl of Liverpool was president), and their lordships, with a laudable solicitude for the public welfare, were pleased, by an order, bearing date at White-

hall, the 18th of September, 1787, to refer the same to "six capital dyers, named in the said order, who were desired to inquire into the facts respecting the said important discoveries in the black and scarlet dyes;" and afterwards "to report to the committee their opinion of the merits and utility" thereof.

It was not, however, until the 22d of January following, that an experiment relating to the scarlet dye was made at the dye-house of Messrs. Goodwin, Platt, and Co., Bankside, Southwark. Considering, on that occasion, how much practical operators, in all the arts, are inclined to distrust improvements offered by speculative men upon the grounds of theory or philosophical reasoning, I was desirous of making my first trial, under the most favourable circumstances, in order that by its signal success, I might effectually obviate the effect of any unfavourable prepossessions in the minds of those who were to report on the merits of my discoveries. For this purpose I prepared a large quantity (near 100lbs.) of the muriatic solution of tin; and in order that the acid might be perfectly saturated with the metal, I added an over-proportion of the latter, and kept both at the boiling point, by means of a sand heat, for the space of three days and nights. In this way I obtained a solution perfectly colourless, of a very pungent smell, and so highly volatile and elastic, that it was impossible to prevent its escape from the vessels in which it was contained, however closely stopped. It was, in fact, but little different from the fuming liquor of Libavius, in which dry muriatic acid is saturated with tin; but this complete saturation, instead of proving beneficial, as I had expected, became an obstacle to my success; because the union between the acid and the metal was thereby rendered so intimate and powerful, that the affinities of the cloth and the colouring matter of the bark could not overcome it,

except in a degree too small to afford a sufficient basis for the cochineal colour; and farther quantities of the solution being therefore added, to supply this deficiency, (from an erroneous notion respecting the cause of it,) the texture of the cloth was by these additions greatly weakened and injured.

Two pieces of long baize, weighing together 188lbs. had been chosen as the objects of this experiment. I had before observed in my private trials, that the colour generally proved most lively when given with a full proportion of the muriate of tin; and also that the colouring matter of the cochineal was most completely imbibed and *taken up* out of the dyeing liquor by the cloth, when the whole portion of the solution of tin, instead of being applied at different times, was boiled up *at once* with the quercitron bark; an effect the more desirable for me at that time, because I intended to employ a very small proportion of cochineal, and therefore wished to leave as little as possible of its colouring matter behind, floating in the dyeing liquor, especially as it would be difficult properly to estimate the exact quantity remaining therein.

For these reasons, I took a large portion of the solution of tin, *i. e.* 16lbs. weight for the two pieces of baize, and threw the whole of it at once, with five pounds of powdered quercitron bark, into a suitable *tin vessel*,* properly filled with water a little warmed, into

* For a considerable number of years, the scarlet colour had been constantly dyed in vessels made, or consisting wholly of block tin. Very lately, however, it has been found that copper bottoms might be given to these vessels without injuring the colour, and with a great saving of expense, as they prove much more durable, and the copper is but little acted upon when secluded from atmospheric air, by being covered with water, &c.; and even in the dyeing operation, the acids are more disposed to exert their *action*

which the pieces of baize (previously moistened) were soon after put, and turned as usual over a winch through the liquor (which was made to boil) for the space of an hour, when they were both taken out and rinced in clean water, the dyeing vessel being at the same time emptied, and then filled again with warm water for the remaining part of the operation. The baize had, in this first boiling, acquired a very bright golden yellow, though but about one-fortieth part of its weight of bark was employed; and I had expected, from what had before happened in my own particular experiments, that it would have been so fully impregnated by the metallic basis, as to want no farther addition of the muriate of tin in the second part of the process. To secure myself, however, against a disappointment on this point, I cut off a bit from one of the pieces, and boiling it in a small pipkin with water, and a little cochineal, I saw with great concern that the fibres of the cloth were very far from having imbibed enough of the oxide of tin to fix and raise the cochineal colour; and that a farther portion of the solution would be absolutely necessary for this purpose. The cause, indeed, of this disappointment, was only ascertained by subsequent experiments, though it might have been conjectured at that time, as the water into which the solution of tin had been poured in the dying vessel, did not decompose any part of it, or become in the slightest degree milky or turbid, as it does with other solutions of of that metal; and the attraction of the woollen cloth was evidently much too feeble to separate and attach to itself any part of the oxide of tin, excepting that which had united with the colouring matter of the bark, and by this additional affinity became fixed in the wool as the basis

upon the *tin* of which the upper part of the vessel consists, and upon the cochineal and the cloth, than on the copper bottom.

of that golden yellow which it had received, as already mentioned; whilst the other and greater part of the oxide remained in the water, (combined with the muriatic acid,) and was thrown away with it after the first boiling, but unfortunately not without having previously weakened the fibres of the wool by its corrosive property, of which I had no suspicion, until it became manifest in the second part of the operation. For this, five pounds of cochineal were put into the dyeing vessel, with six pounds more of the muriate of tin, and being well mixed in the water, the two pieces of baize were put into the liquor, and dyed therein for about fifteen minutes, when the colour not seeming to rise properly, four pounds more of the solution of tin, and one pound of cochineal, were added; and the dyeing was continued, until it appeared soon after that the texture of the cloth was greatly injured by the muriate of tin,* which seemed in this, as well as in subsequent trials, to have a much stronger and more corrosive action upon the fibres of wool than other solutions of that metal, though before that time I had always been persuaded that it would on the contrary have acted more mildly in this respect than the ordinary dyer's solution or spirit; and indeed I had been led to this persuasion by the concurrent opinions of several very eminent chemists, who had all represented the ni-

* Subsequent experiments have proved, that if my purpose of employing the yellow of the quercitron bark, in conjunction with a rose colour from cochineal, would have allowed me to add the usual portion of tartar on this occasion, the injury sustained by the cloth might have been completely obviated; for the acid of the tartar, like every other acid which I have tried, greatly corrects this hurtful sort of action, which the muriate of tin, when employed *alone*, exercises on wool or woollen stuffs. The tartar would, moreover, have rendered the muriate of tin more susceptible of *decomposition*, by affording a portion of superfluous or uncombined *acid*, so that *less* of the muriate of tin would have been sufficient.

tric acid as exerting a stronger and more corrosive action than the muriatic upon animal substances. Even that very excellent chemist Berthollet has observed, in tenth volume of the Ann. de Chimie, published so lately as the month of August 1791, and after he had been particularly employed in examining the effects of the different acids upon wool and silk, that "l'acide sulphurique et l'acide muriatique exercent une action moins vive sur les substances animales que l'acide nitrique suffisamment concentré." And this doubtless is true of these acids acting merely as acids; but very different properties appear to result from their combinations with metals, and metallic substances; among which, the metallic solutions by muriatic acid seem generally more corrosive than those made by any other. This is particularly true of the muriates of mercury, silver, lead, bismuth, and antimony, as well as that of tin; but the corrosive nature of this last, and the difficulty of decomposing it, seem to be increased, in proportion as the muriatic acid is more completely saturated or combined with a greater portion of the metal. It is indeed true, that the proportion of solution of tin used in the foregoing experiment, was much greater than I had ever before employed, as it amounted to 26lbs., and contained above six pounds of the metal, which is four times as much as would suffice (dissolved by a mixture to be hereafter explained) for the same weight of cloth. But still I am persuaded, that an equal quantity of any other solution of tin would not have injured the like quantity of cloth in an equal degree; and being thus made sensible of the danger that must attend the use of a mordant so corrosive, I was convinced of the expediency of searching for one more harmless in this respect, though it certainly is very possible, with proper care, to employ the muriate of tin (containing a smaller proportion of the metal) so as to produce all the

good effects which I had expected from it, without any injury to the cloth, as I have found by a multitude of experiments since, as well as before, that of the 22d of January, 1787.

Whence this corrosive property of the muriate of tin arises, may become a subject of future inquiry. At present, I shall only observe, that in some experiments which I made, with a hope of correcting it, I constantly found this saturated muriate of tin possessing a strong attraction for oxygene, and that by absorbing it, as it did from various matters, its corrosive property was always greatly diminished. This led me to oxygenate the muriatic solution of tin, by putting a very little manganese into it, or rather by dissolving tin with a very little manganese in muriatic acid; but though the solution made in this way appeared less corrosive, it contained a small portion of the manganese, which darkened the cochineal colour, making it incline towards a purple.

I afterwards oxygenated the muriatic acid, by mixing it with about one-third less than its own weight of the nitric, and with this I made a solution of tin; which appearing to be no more corrosive than the common dyers' spirit, and not changing the cochineal crimson towards the yellow hue, I was hastily induced to venture with it upon another trial at the dye-house of Messrs. Goodwin and Co., a few weeks after the first. It was, however, made only on one piece of baize, weighing about ninety pounds, which I caused to be boiled with about eight pounds of this murio-nitric solution of tin, and two pounds and one half of powdered quercitron bark. This mordant, however, acted very feebly, or rather failed, in exalting the *yellow* colour of the bark, which took but very slowly on the baize, and never rose much higher than a straw colour, even after two hours boiling; when a considerable quantity of yellow colour, united to the

calx of tin, evidently remained floating in the water, not because the calx was too intimately combined with the acid solvent, as in the first experiment,—but because, for want of a sufficient attraction between them, it had been almost wholly decomposed as soon as they were put into water: and in boiling, it fixed itself with the bark colour upon the cloth very sparingly, superficially, and slowly. This also happened in the second part of the operation; for which three pounds of cochineal, and six of this murio-nitric solution of tin, were at first employed; but the colour not rising sufficiently, another pound of cochineal, with four pounds more of the same solution, were added to the liquor in which the cloth was dyed for the space of two hours, when a considerable part of the colour still appeared floating, but not dissolved, in the water. So much, indeed, had been applied to the cloth, as to give it a passable scarlet colour, which, however, had penetrated but very little into its substance, so that the cloth seemed, as Mr. Goodwin observed, to have been rather *painted* than dyed.* It was, however, generally

* According to my best recollection, the solution of tin employed for this experiment had been made eight or ten days before it was so employed, and during this interval the metal had probably become too much oxygenated: and it had moreover the disadvantage of being used without the aid of tartar, which by its acid seems to enable the oxide of tin, as well as the cochineal colour, to penetrate and unite more copiously with the fibres of wool. I very lately (Nov. 1812), mixed three ounces of strong nitric acid of the specific gravity of 1500, with seven ounces of muriatic acid of the specific gravity of about 1165. The mixture, as is usual, effervesced, and assumed for a short space of time a deep red colour. In this mixture diluted with six ounces of water, I dissolved two ounces of fine granulated tin, and the *next day* employed a suitable portion of it, with cochineal and cream of tartar, to dye a small piece of broad-cloth. I observed, on putting the solution of tin into the water, that it collected therein like small loose dispersed *curds*, which, however, by a little boiling with the tartar, were completely dissolv-

agreed, after a particular examination, that notwithstanding the great length of time in which the baize had been boiled with a very large proportion of the solution of tin, (*i. e.* 18lbs. for a single piece weighing but 90lbs.), its texture had not received the smallest injury; so that in this respect my last experiment proved less expensive than the first, though both together cost me nearly 30*l.*

As this murio-nitrate of tin, though exempt from the defects of the muriatic solution, had failed through others of a very opposite nature, I was induced to mix much greater proportions of nitric with the muriatic acid for dissolving tin, in order to see how much of the former could be used in this way, without so far yellowing the cochineal crimson as to preclude the use of any of the quercitron yellow in the dyeing of scarlet, an effect which I still expected from the nitric acid, when used in a very large proportion; but, to my great surprise, I could discover no such effect, even when I had dissolved the metal in nitric acid *alone*. At first I suspected some impurity in the acid which had been employed; but having

ed, and the cloth being put into this liquor with a part of the cochineal, and boiled in it as usual, and afterwards dyed with the remainder of the cochineal and more of the solution of tin and tartar, imbibed, contrary to my expectation, a *very bright good scarlet*, excepting that it inclined a little too much to the orange tint. In this case the colour had penetrated and united itself to the cloth as expeditiously as with the solution of tin commonly employed by the dyers, and without any such difficulty as I had experienced in my second experiment at the dye-house of Messrs. Goodwin and Co.; an advantage which must, as I think, have resulted from my having in this latter trial employed the solution of tin when *recently* made, and in conjunction with the tartar, which was omitted in the former: but I will endeavour to ascertain the truth on this point by future trials with the same solution, after it has been kept during various longer periods, and also with and without the co-operation of tartar, and mention their results in a postscript to my second volume.

procured a fresh supply, and ascertained its purity by the proper means, I still found that tin dissolved by it had not the least tendency to change the cochineal crimson towards a yellowish or scarlet hue; and *that this effect, in the usual way of dyeing that colour, resulted wholly from the tartar,* (acidulated tartrite of potash,) *which is always employed at the same time.* This fact I ascertained by repeated and varied experiments, in which I constantly found that cochineal, with the dyers' common solution of tin, and even with that made by nitric acid only, would produce nothing but a crimson without tartar; and that cochineal, *with tartar*, would produce *a scarlet*, not only with these last mentioned solutions, but also, *and equally well*, with the *muriatic solution of that metal;* and therefore, that every thing which had been taught and believed to the contrary was repugnant to truth. And here I cannot conceal my wonder, that an error of so much consequence, and so destitute of all foundation, should have been propagated and confirmed by so many acute reasoners and sagacious observers in other respects; for, besides those eminent writers already mentioned, Mr. Pœrner has more recently adopted and propagated the same error, after making a great number of experiments, several of which, if they had been duly considered, would have taught him the truth on this subject.* This also was even more lately done by M. Berthollet, in his Elémens de l'Art de la Teinture, where, to adopt the words of Dr. Hamilton's translation, he says, "Tartar, as we have seen, gives a *deeper* and *more rosy hue* to the colouring matter of cochineal, precipitated by the solution of tin. It moderates the action of the nitro-muriatic acid, which tends to give scarlet an orange cast, though this orange cast is not to be seen in the precipitate produced by the

* See Instruction sur l'Art de la Teinture, &c. à Paris, 1791.

solution of tin, which is on the contrary of a fine red. It is probable that the solution of tin gives scarlet an orange tinge, by means of the action the nitro-muriatic acid exerts on the wool, which, as well as all other animal substances, it has the property of turning yellow."*

"Thus (adds he,) by putting more of tartar into the reddening, a deeper and fuller scarlet may be obtained; and on the contrary, the scarlet may be rendered more inclining to orange by omitting this ingredient." And he concludes the chapter by repeating this doctrine.

Here then it is manifest, that the nitro-muriate of tin and the tartar are each supposed to produce effects *directly contrary to those which are really produced* by them, the effects of each being ascribed to the other; a mistake capable of producing much disappointment and detriment.†

* It is true that nitric acid alone makes wool, &c. yellow; but wool or cloth, boiled with nitro-muriate of tin, as a preparation for scarlet, remains perfectly white, if no colouring is mixed with it, as is well known.

† M. Berthollet, with his usual and becoming *candour*, has, in the *last* edition of his Elements, &c. admitted the *error* into which he had fallen, in common with all others, on this subject, and the truth of my observations respecting it. "On avoit, (says he,) dans la première édition de ces élémens, attribué au tartre la propriété de donner une nuance plus foncée et plus rosée aux parties colorantes de la cochenille: cette opinion pouvait même être regardée comme générale; *mais Bancroft l'a combattue avec raison:* il prétend que si l'on supprime le tartre, on a une couleur cramoisie; que le tartre donne naissance à un tartrite d'étain insoluble, qui fait avec la cochenille une couleur jaune; que l'écarlate ordinaire est un mélange d'un quart de cette couleur jaune et de trois quarts ou un peu plus de la couleur cramoisie que donne la cochenille avec la dissolution d'étain," &c. And after mentioning my proposal for obtaining the yellow part of the scarlet colour from the quercitron bark, rather than from cochineal, he gives an account of three experiments which he had made by dyeing cloth with cochineal and a solution of tin; for two of which he also employed tartar in the ordinary,

Having made myself certain that the dyers' spirit, or nitro-muriatic solution of tin, without tartar, would only dye a crimson with cochineal, I was induced to make an experiment therewith, instead of the muriate of tin, at the dye-house of the late Mr. Seward, in Goswell-street, and with views similar to those which directed the experiments before made at the dye-house of Messrs. Goodwin and Co. A piece of baize was accordingly boiled one hour and a quarter with the usual portion of nitro-muriatic solution of tin, (which had been prepared by Mr. Seward,) and with about one-fortieth of its weight of quercitron bark, without any tartar: after which it was taken out dyed of a bright yellow, though paler than it

and in a double proportion: and he found that in proportion to the quantity of tartar employed, the colour inclined to the yellow tint, whilst that without tartar "avoit couleur *vineuse* et moins vive," &c. He adds, "*il est donc vrai* que le tartre fait incliner *au jaune* la couleur de la cochenille, et qu'il produit d'autant plus cet effet, que la proportion en est plus grande," &c. Elémens, tom. ii. p. 179, 180.

I must observe, however, that the explanation here given by M. Berthollet, of my conclusions in regard to the effects of tartar in the dyeing of scarlet, is not quite correct. I have never intended to decide, that the acid of tartar formed an *insoluble* tartrite of tin, and that this tartrite changed the colour of a *part* of the cochineal to a pure yellow, and thereby gave to the other part a *scarlet* tint; though I have in fact supposed this as an *ultimate* effect to result from the action of tartar. But I intended to leave it undecided, whether the acid of tartar acted conjointly with the other acids and the tin, or separately with the metal, in producing a scarlet instead of the *rose* colour, which would have been produced without it; and though I supposed the amount of this change to be equivalent to a conversion of nearly one-fourth of the cochineal colour to a *yellow*, yet I did not assume that the change in question had been operated or effected in a *fourth* or any other part *exclusively*, rather than on the whole collectively. Indeed, I have never found the *tartrite* of tin, even when employed *alone* with cochineal, able to render the colour *yellow*, though it produces a very *yellowish* scarlet.

would have been with the muriate of tin. The baize being rinced, and the dyeing vessel emptied, and then filled a second time with clean water, about four-fifths of the cochineal usually employed for the like quantity of baize, and a farther suitable proportion of the solution of tin, were put into it, and the baize being dyed therein, as usual, took what was allowed to be a good scarlet. Mr. Seward, however, did not seem so fully convinced, as I had expected, of the advantage of compounding a scarlet in this way from the cochineal crimson and quercitron yellow; and probably the experiment had not been attended with any very manifest success, or saving of cochineal; because the nitro-muriatic solution of tin which had produced but a pale yellow with the quercitron bark, had also acted more feebly in raising or exalting the cochineal colour than it usually does when assisted with tartar, which consists of a portion of vegetable alkali combined with an excess of its own peculiar acid; and therefore, whenever it is mixed with a solution of tin by any of the mineral acids, the tartar will be decomposed; because the mineral acids, by their superior attraction for, will unite with its alkaline basis, and disengage an additional portion of the tartarous acid, which will then unite with the metallic oxide, previously abandoned by the mineral acid, and thus produce a *tartrite of tin*, which last, in the usual way of dyeing scarlet, inclines the cochineal crimson to the yellow tint, and at the same time, (as I have since found,) exalts its colour more than the nitro-muriatic solution of tin alone would be able to do; and it is only this decomposition of the tartar, that has obviated the ill effects which otherwise must have resulted from the sulphuric acid, frequently contained in the common aqua-fortis used by the scarlet dyers.*

* This statement, first made in 1794, respecting the effects of tartar with sulphuric acid, is partly erroneous, or liable to miscon-

Though I had hitherto failed in my endeavours to compose a scarlet colour with advantage, so as to save that part of the cochineal which appeared to be misapplied, by being yellowed in the usual process, I had nevertheless full confidence in my former reasoning on this subject, and employed myself from time to time in searching after more suitable means for attaining this end. Some of my earliest experiments with a solution, or rather a calcination of tin by the sulphuric acid, had shown me that this preparation was very unsuitable for my purpose, because it really exerted a destructive action on the cochineal colour, by reducing it from a crimson down to a kind of salmon colour, which indeed was the highest colour pro-

ception: wherever that acid (the sulphuric) acts upon tin, either *alone*, or with any mixture containing *nitric* acid, the oxide of that metal, probably by too much oxygenation, is brought into a state which renders it incapable of producing with cochineal any thing better, or approaching nearer to scarlet than an orange, or at most a *high salmon colour*. It is true, indeed, that if oil of vitriol be put either into the scarlet dyeing, or the preparation liquors, immediately after, or conjointly with the tartar, *it will do no harm*, provided the quantity be only sufficient to *decompose the tartar, and neutralize* its alkaline part. But as no tartar is employed by the dyers in making their ordinary solution of tin, and as the aqua-fortis used for that purpose, frequently contains a little sulphuric acid, the latter will have produced all its mischievous effects upon the tin, previously to the dyeing operation, and these effects will not afterwards be overcome by the tartar employed in that operation. Fortunately, however, the mischief which might be produced by a little sulphuric acid mixed with the aqua-fortis employed by the dyers to dissolve their tin, is commonly *obviated*, without their being sensible of it, by their practice of making a nitro-muriatic acid, not by mixing the muriatic *simply* with the nitric acid, but by adding to the latter a portion either of sea-salt, or of muriate of ammonia, either of which affords an alkali, which, by its stronger affinity for the sulphuric, than for either the nitric or muriatic acids, combines with and neutralizes the former, when the quantity is not too great, and thus renders it harmless.

duced on cloth by dyeing it with cochineal and sulphate of tin; I therefore discarded the use of sulphuric acid for dissolving tin, until particular circumstances led me some time after to dissolve a portion of it by the muriatic acid, combined with about one-fourth of its weight of oil of vitriol; and by trying this solution, I found that it produced very good effects in dyeing, without any appearance of that corrosive property which had acted so mischievously in the experiments made with tin, dissolved by muriatic acid only. I was therefore encouraged to make and try other solutions of that metal, by the same acids, united in various proportions; and have at length found reason to prefer a solution made by dissolving after the rate of about fourteen ounces of tin in a mixture of two pounds of oil of vitriol, (of the usual strength,) with about three pounds of muriatic acid. That which I have used was of the specific gravity of nearly 1170, and strong enough, with a sand-heat, to dissolve one-third of its weight of tin. The muriatic acid should be first poured upon a large quantity of granulated tin, in a capacious glass receiver, and the oil of vitriol afterwards added slowly; and these acids being mixed, should be left to saturate themselves with tin, which they will do in a longer or shorter time, according to the temperature of the atmosphere, without any artificial heat; but the solution may be rapidly promoted by a sand-heat.

This solution contained but little more than half as much tin as the muriatic solution which had been used in the first experiment made at the dye-house of Messrs. Goodwin and Co., yet the metallic part of it existed in a state so much more suitable for the purposes of dyeing, that a given quantity of it would produce much better effects than a like quantity of muriatic solution, containing nearly twice as much of the metal, and without any corrosive property, capable of doing the least mischief,

unless used in much greater proportions than ever can be wanted for dyeing.*

The murio-sulphuric solution of tin, made in these proportions, will be perfectly transparent and colourless; and will probably remain so for many years, without becoming turbid, or suffering by any precipitation of the metal; at least, none has appeared in some which I have kept for more than three years. It will produce full twice as much effect as the dyers' spirit, or nitro-muriatic solution of tin, with less than a third of the expense. It has, moreover, the property of raising the colours of, I believe, all adjective dyes, more than the dyers' spirit, and full as much as the tartrite of tin, without changing the natural crimson of cochineal towards the yellowish hue; and, therefore, after having made a great number of experiments with it, I think myself warranted in strongly recommending this murio-sulphate of tin for dyeing the compound scarlet colour already described, (with the cochineal crimson and quercitron yellow,) for which it will be found highly effectual and economical.

For this species of scarlet nothing is necessary but to put the cloth, suppose 100lbs. weight, into a proper tin vessel, nearly filled with water, in which about eight pounds of the murio-sulphuric solution of tin have been previously mixed, to make the liquor boil, turning the cloth as usual through it, by the winch, for a quarter of an hour; then turning the cloth out of the liquor, to put into it about four pounds of cochineal, and two pounds and a half of quercitron bark in powder, and having mixed them well, to return the cloth again into the liquor, mak-

* Since my first edition of this volume was published, I have ascertained that even the proportion of tin here mentioned is unnecessarily great, and that equally good effects may be obtained with the same quantity of acids, when the latter contain but little more than half the quantity of tin which they are capable of dissolving.

ing it boil, and continue the operation as usual until the colour be duly raised, and the dyeing liquor exhausted, which will be the case in about fifteen or twenty minutes; after which the cloth may be taken out and rinced as usual. In this way the time, labour, and fuel, necessary for filling and heating the dyeing vessel a second time, will be saved; the operation finished much more speedily than in the common way; and there will be a saving of all the tartar, as well as of two-thirds of the cost of spirit, or nitro-muriatic solution of tin, which for dyeing 100lbs. of wool, commonly amounts to 10*s.*; whereas, eight pounds of the murio-sulphuric solution will only cost about 3*s.* There will be, moreover, a saving of at least one-fourth of the cochineal usually employed, (which is generally computed at the rate of one ounce for every pound of cloth,) and the colour produced will certainly not prove inferior in any respect to that dyed with much more expense and trouble in the ordinary way. When a rose-colour is wanted, it may be readily and cheaply dyed in this way, only omitting the quercitron bark, instead of the complex method now practised of first producing a scarlet, and then changing it to a rose by the volatile alkali contained in stale urine, set free or decomposed by potash or by lime: and, even if any one should still *unwisely* choose to continue the practice of dyeing scarlet without quercitron bark, he need only employ the usual proportions of tartar and cochineal, with a suitable quantity of the murio-sulphate of tin, which, whilst it costs so much less, will be more effectual than the dyers' spirit.*

* The murio-sulphate of tin here recommended, is now employed by the dyers in many parts of England, particularly in Yorkshire and Lancashire, though many of them do not know how, or with what acids it is prepared. A considerable distiller of aqua-fortis, and of muriatic acid, who also prepares solutions of tin in large quantities, in-

Several hundreds of experiments warrant my assertion, that at least a fourth part of the cochineal generally employed in dyeing scarlet, may be saved by obtaining so much yellow as is necessary to compose this colour from the quercitron bark; and indeed nothing can be more self-evident, than that such an effect, *cæteris paribus*, ought necessarily to result from this combination of different colouring matters, suited to produce the compound colour in question. Let it be recollected that the cochineal crimson, though capable of being changed by the acid of tartar towards the yellow hue on one hand, is also capable by different means, of being changed towards a blue on the other, and of thereby producing a purple without indigo or any other blue colouring matter: yet I am confident that nobody would believe a pound of cochineal so employed, capable *alone* of dyeing as much cloth, of any particular shade of purple, as might be dyed with it, if the whole of its colouring matter were employed solely in furnishing the crimson part of the purple, whilst the other (blue) part thereof was obtained from indigo. To say that a pound of cochineal *alone* could produce as much effect or colour as a pound of cochineal and a pound of indigo *together*, would be an improbability much too *obvious* and *palpable* for human belief; and there certainly would be a similar improbability in al-

forms me that he is in the practice of selling this preparation of that metal, *under another denomination*, and that it is chiefly employed to dye the most vivid and beautiful yellows from quercitron bark. It has also been of late used to dye scarlet with a preparation called lac lake, made (in the East Indies) from the stick lac, to be noticed in my next chapter.

Mr. Hawker (near Stroud, in Gloucestershire,) lately mentioned at p. 337, told me, in 1795, soon after the publication of my first edition, that he had prepared the murio-sulphate of tin, according to my direction, and found it answer the purpose for which it had been recommended by me.

leging, that a pound of cochineal, employed in giving another compound colour (scarlet), could alone produce as much effect as a pound of cochineal and a pound of quercitron bark, when the colour of this last was employed only in furnishing one of the component parts of the scarlet, for which a considerable portion of the colouring matter of the cochineal must otherwise have been expended, which certainly happens in the new mode of dyeing scarlet, because the colour produced with an addition of the quercitron yellow inclines no more towards a yellow, than the scarlet produced by yellowing a part of the cochineal colour in the usual method with tartar. I retain, therefore, at this moment, as much confidence as I ever had in the reality and importance of my proposed improvements in this respect.*

The scarlet composed of cochineal crimson and quercitron yellow, is moreover attended with this advantage, that it may be dyed upon wool and woollen yarn, without any danger of its being changed to a rose or crimson, by the process of fulling, as always happens to scarlet dyed by the usual means. This last being in fact nothing but a crimson or rose colour, yellowed by some specific or particular action of the acid of tartar, is liable to be made crimson again by the application of many chemical

* Of the benefit which I formerly expected to obtain by employing potash or soda to extract a part of the cochineal colour, which water alone did not appear capable of extracting, it must be remarked, that I have some time since convinced myself of its being an illusion; for, by repeated trials, I have found that the solid parts of powdered cochineal remaining after it has been boiled with the solution of tin and tartar, as in the common dyeing process, yield no colour worthy of notice, upon the application of potash; the solution of tin and tartaric acid, enabling the water to extract the colour sufficiently; so that in truth there is no such waste of cochineal colour as I had supposed, in the usual way of employing that drug.

agents, (which readily overcome the changeable yellow produced by the tartar,) an particularly by calcareous earths, soap, alkaline salts, &c. But where the cochineal colouring matter is applied and fixed merely as a *crimson* or *rose* colour, and is rendered scarlet by superadding a very *permanent quercitron yellow*, capable of resisting the strongest acids and alkalies, (which it does when dyed with solutions of tin,) no such change can take place, because the cochineal colour having never ceased to be crimson, cannot be rendered more so, and therefore cannot suffer by those impressions or applications which frequently change or spot scarlets dyed according to the present practice.*

There is also a singular property attending the compound scarlet dyed with cochineal and quercitron bark; which is, that if it be compared with another piece of scarlet dyed in the usual way, and both appear by daylight *exactly of the same shade*, the former, if they be afterwards compared by candle-light, will appear to be at least several shades higher and fuller than the latter; a circumstance of some importance, when it is considered how much this and other gay colours are generally worn and exhibited by candle-light during a considerable part of the year.

To illustrate more clearly the effects of the murio-sulphuric solution of tin with cochineal in dyeing, I shall state a very few of my numerous experiments therewith;

* MM. Thenard and Roard, in their "Mémoire sur les mordants employés dans la teinture,†" observe, that ever since the discovery of scarlet, its liability to become crimson has been *complained of, without any attempt to ascertain and obviate the cause of that defect.* In making the latter part of this observation, they must surely have forgotten, or never have been made acquainted with this part of my publication, which had preceded their memoir sixteen years.
† annales de Chimie, Tom. 74, p. 267.

observing, however, that they were all several times repeated, and always with similar effects.

1st. I boiled one hundred parts of woollen cloth in water, with eight parts of the murio-sulphuric solution of tin, during the space of ten or fifteen minutes; I then added to the same water four parts of cochineal, and two parts and a half of quercitron bark in powder, and boiled the cloth fifteen or twenty minutes longer; at the end of which it had nearly imbibed all the colour of the dyeing liquor, and received a very good, even, and bright scarlet. Similar cloth dyed of that colour at the same time in the usual way, and with a fourth part more of cochineal, was found upon comparison to have somewhat less body than the former; the effect of the quercitron bark in the first case having been more than equal to the additional portion of cochineal employed in the latter, and made yellow by the action of tartar.

2d. To see whether the tartrite of tin would, besides yellowing the cochineal crimson, contribute to raise and exalt its colour more than the murio-sulphate of that metal, I boiled one hundred parts of cloth with eight parts of the murio-sulphuric solution, and six parts of tartar, for the space of one hour; I then dyed the cloth, *unrinced*, in clean water, with four parts of cochineal, and two parts and a half of quercitron bark, which produced a bright aurora colour, because a double portion of yellow had been here produced, first by the quercitron bark, and then by the action of tartar upon the cochineal colouring matter. To bring back this aurora to the scarlet colour, by taking away or changing the yellow produced by the tartar, I divided the cloth whilst unrinced into three equal parts, and boiled one of them a few minutes in water, slightly impregnated with potash; another in water with a little ammonia; and the third in water containing a very little powdered chalk, by which all the

pieces became scarlet; but the two last appeared somewhat brighter than the first, the ammonia and chalk having each rosed the cochineal colour rather more advantageously than the potash. The best of these, however, by comparison, did not seem preferable to the compound scarlet dyed without tartar, as in the preceding experiment; consequently this did not seem to exalt the cochineal colour more than the murio-sulphate of tin; had it done so, the use of it in this way would have been easy, without relinquishing the advantages of the quercitron yellow.

3d. I boiled one hundred parts of woollen cloth with eight parts of the murio-sulphuric solution of tin, for about ten minutes, then added four parts of cochineal in powder, which by ten or fifteen minutes more of boiling, produced a fine crimson. This I divided into two equal parts, one of which I yellowed or made scarlet by boiling it for fifteen minutes with a tenth of its weight of tartar in clean water; and the other, by boiling it with a fortieth of its weight of quercitron bark, and the same weight of murio-sulphuric solution of tin; so that in this last case there was an addition of yellow colouring matter from the bark, whilst in the former no such addition took place, the yellow necessary for producing the scarlet having been wholly gained by a change and diminution of the cochineal crimson or rose colour; and the two pieces being compared with each other, that which had been rendered scarlet by an addition of quercitron yellow, was, as might have been expected, several shades fuller than the other.

4th. I dyed one hundred parts of woollen cloth scarlet, by boiling it first in water with eight parts of murio-sulphate of tin, and twelve parts of tartar, for ten minutes, and then adding five parts of cochineal, and continuing the boiling for fifteen minutes. This scarlet cloth I divi-

ded equally, and made one part crimson, by boiling it with a little ammonia in clean water; after which I again rendered it scarlet, by boiling it in clean water with a fortieth of its weight of quercitron bark, and the same weight of murio-sulphate of tin; and this last, being compared with the other half, to which no quercitron yellow had been applied, was found to possess the most colour, as might have been expected. A piece of the cloth, which had been dyed scarlet by cochineal and quercitron bark, as in the first experiment, being at the same time boiled in the same water with ammonia, did not become crimson, like that dyed scarlet without the bark.

In this way of compounding a scarlet from cochineal and quercitron bark, the dyer will at all times be able, with the utmost certainty, to produce every possible shade between the crimson and yellow colours, by only increasing or diminishing the proportion of bark. It has, indeed, been usual at times when scarlets, approaching nearly to the aurora colour, were in fashion, to superadd a fugitive yellow either from turmeric, or from what is called young fustic (rhus cotinus;) but this was only when the cochineal colour had been previously *yellowed as much as possible by the use of tartar*, as in the common way of dyeing scarlet; and therefore that practice ought not to be confounded with my improvement, which has for its object to preclude the loss of any part of the cochineal rose or crimson, by its conversion towards a yellow colour, which may be so much more cheaply obtained from the quercitron bark.

By sufficient trials, I have satisfied myself that the cochineal colours, dyed with the murio-sulphuric solution of tin, are in every respect at least as durable as any which can be dyed with any other preparation of that metal; and they even seem to withstand the action of boiling soap-suds somewhat longer, and therefore I cannot avoid

earnestly recommending its use for dyeing rose and other cochineal colours, as well as for compounding a scarlet with the quercitron bark.

Having ascertained about the time of the publication of my first edition of this volume, that the *red* colour afforded by madder, might be greatly *exalted* and *brightened* by employing it with the murio-sulphate of tin, and indeed, with the nitro-muriate and the muriate of that metal, (instead of alum,) and that the *lively yellowish red* so produced, was *extremely durable*, it occurred to me, that there might be an advantage at least for ordinary scarlets, in substituting the *madder* for the quercitron bark, to compose a scarlet with cochineal, on the principle before explained; because the former might be made not only to supply the *yellow* part of the scarlet, but also a portion of *red*, *in aid* of the cochineal colour, without perceptibly detracting from the vivacity of the latter;—with this expectation, I soon after made a great number of experiments, which fully answered my expectation, and proved by their general results, that cloth prepared by boiling the usual time with murio-sulphate of tin, (the acids not being saturated by the metal,) and without tartar, and afterwards dyed with cochineal and the finest Zealand madder, in the proportion of from two to three or even four pounds of the latter, with one of the former, might be made to acquire a good scarlet, with a saving of one fourth or one fifth of the cochineal, which would have been necessary to produce it *alone*. When more of madder than the proportion just mentioned was employed, the colour, if *contrasted* with a *very fine* scarlet, appeared to incline towards a yellowish brown tint, though, to common eyes, this would be hardly perceived without such contrast. It must, however, be admitted, that for scarlets which are intended to *excel* and vie with those of Mr. Nash or his successor, it would be advisable to employ

cochineal alone, or with the quercitron yellow instead of the madder red, cheapness being for them of less importance than beauty of colour. But for ordinary scarlets, I am convinced it may be employed as just mentioned, without any perceptible degradation of the colour, and with a considerable diminution of expense.

I have thus freely given the results of a multitude of experiments, on which I have expended money, with much more of time and meditation; and though some years may elapse before the truth and importance of what I here offer are fully recognized, I am confident this will happen sooner or later; and by putting it into every one's power to bring my ideas to the test of experience, I shall have at least done my duty.*

I had not particularly directed my attention to the dyeing of scarlet, until the year 1786, when no person, so far as I have been able to discover, had ever attempted to ascertain the effects of any solution or preparation of tin, excepting that with the nitric or nitro-muriatic acids upon the colouring matter of cochineal; and I shall therefore state the results of numerous experiments which I have since made, with that metal, differently combined, and at various degrees of oxidation, omitting all details respecting proportions, and modes of conducting the dyeing operations, which are to be understood as having been conformable to the common practice where nothing is mentioned to the contrary.

Woollen cloth, dyed with cochineal and pure nitrate of tin recently prepared, produced a fine crimson, and this,

* A portion of yellow colouring matter, obtained either from the quercitron bark or the rhus cotinus, is now (1812,) very generally employed in this country with cochineal, for dyeing scarlet; not indeed, without tartar, but with a smaller quantity than that which is employed in other countries, and which was formerly employed in this.

boiled in the same liquor with tartar, was changed to a good scarlet. A similar, but rather better effect was produced by tin dissolved immediately in a mixture of aqua-fortis and tartar. The scarlet given by this tartaro-nitrate of tin appeared highly beautiful.

Tin put into aqua-fortis, with a considerable portion of refined sugar, afforded a very thick adhesive solution, which assumed a blackish brown colour, like that of *burnt sugar*, and being tried as a mordant in dyeing, it was found incapable of fixing the cochineal or any other colours. The tin in this state did not seem fitted to combine with the fibres of the cloth, and the sugar had manifestly suffered a kind of combustion, having probably in this case produced, upon the tin, as it does with indigo, (see p. 161,) a *deoxygenating* effect. Spirit of wine, put with tin into aqua-fortis, also rendered the solution unfit to serve as a mordant, and, as I conclude, by a similar deoxygenation.

Tin, granulated and calcined with an equal quantity of saltpetre, in a red-hot crucible, being thrown into water, afforded a milky solution, tasting very sensibly of the alkaline part of the saltpetre, and evidently suspending a considerable portion of the metallic calx. Cloth boiled in water with some of this solution, then rinced, and dyed with cochineal, took a crimson, inclining to the purple; and this, boiled in the same liquor with tartar, was changed to scarlet.

Having poured two pounds of aqua-fortis, with an equal weight of water, upon a large quantity of granulated tin, and left them together during the three summer months of 1790, I afterwards found near a pound of the calx of tin collected in solid lumps at the bottom of the glass vessel. This being separated and dried, some of it was finely powdered and *thoroughly washed;* and being put with an equal weight of cochineal into water, I boiled

cloth therein, which took a full equal crimson, somewhat deficient in brightness.* Tartar being added to the liquor, and the cloth farther boiled therein, it acquired a good scarlet. Lemon juice used, instead of tartar, produced the like effect. By substituting caustic volatile alkali for tartar and lemon juice, a crimson, greatly inclining to purple, was produced. The oxide of tin, therefore, does not act in all cases *merely as such*, but its effects often depend on triple, quadruple, and sometimes even more complex combinations, in which different saline and other parts of the compound remain permanently united, at least where the shades of colour depending on them are found permanent. It is thus that sea-salt, and other purely saline matters, which, having no earthy or metallic basis, cannot become the basis of any adjective colour, produce *lasting* effects in modifying and varying the shades of different colours.†

It must, however, be observed, that though the calx of tin, just mentioned, was, after being thoroughly wash-

* The calx or oxide of tin employed for this experiment, was some of that which is mentioned at pages 159 and 160, as having efficaciously *de*oxygenated indigo: consequently it was far from being in the state of a peroxide, or at the maximum of oxygenation; in which state I consider tin as being incapable of producing with cochineal any thing more red or elevated than an orange, or a salmon colour, at the most.

† Hellot describes, at p. 234, a "*Cramoisi de Languedoc*," which was dyed with cochineal upon cloth, prepared as for the scarlet dye, excepting, that instead of tartar, sea-salt was added to the solution of tin; which addition caused the colour to incline towards the purple or dark crimson; an effect which all the mineral acids seem to produce with cochineal, when neutralized by soda, and more especially by potash; and therefore, in making the common dyers' spirit, when nitric and muriatic acids, *perfectly free* from the sulphuric, can be had, it would be better to employ the muriatic acid instead of sea-salt, especially when very bright scarlets are wanted.

ed and dried, capable of dyeing a crimson on woollens with cochineal, and a scarlet, where either tartar, lemon juice, or quercitron bark were added, it would not permanently combine with, or become the basis of, these colours upon cotton; and indeed, on woollen it was only the finer particles of the calx which really combined with the colouring matter and the wool, the grosser being always distinctly found at the bottom of the dyeing vessel; and when I attempted to impregnate woollen cloth with this oxide of tin only by boiling them together, I always found, on rincing the cloth, and endeavouring to dye it with cochineal in a different vessel or bath, that the oxide had not penetrated or united with the wool, so as to afford a basis for raising and fixing the colour, it being necessary for this purpose, that both the oxide and the colouring matter should be mixed together in the dyeing vessel, and exert their mutual attractions for and upon each other, before they could be properly taken up by the cloth; and this was done better after they had been previously mixed and left together for several hours.

One ounce of the calx of tin before mentioned, unwashed, being dissolved in three ounces of muriatic acid, and woollen cloth being dyed with a tenth of its weight of this solution, and a twentieth of cochineal, it took but a very languid colour. The oxide of tin, (probably from too much oxidation,) being immediately decomposed upon its intermixture with water, and manifesting very little disposition to penetrate or combine with the fibres of the wool; so that after long boiling, a great part of it, and of the colouring matter, remained suspended in the dyeing liquor, as in my second experiment at the dye-house of Messrs. Goodwin and Co.

Cochineal with a solution of tin by muriatic acid only, dyed a beautiful crimson or rose colour; and with a solu-

tion of that metal, by a mixture of tartar and muriatic acid, a beautiful scarlet.

Cochineal, with tin dissolved by a mixture of muriatic and pyroligneous acid, produced a dark crimson; and with tin, and a little manganese dissolved in muriatic acid, it produced a very bluish crimson.

Cochineal, with tin dissolved by muriatic acid and borax mixed, dyed a very good crimson.

Cochineal, with tin calcined by the long continued action of sulphuric acid, dyed a salmon colour; and with a recent solution of tin, it produced a reddish salmon colour, inclining a little to the crimson. A like colour was produced with tin dissolved by equal parts of sulphuric and nitric acids mixed.

Oil of vitriol, having been poured upon tartar and granulated tin, the mixture immediately became black, by the action of the sulphuric acid upon the carbonic basis, which, with hydrogene and oxygene, are the constituents of tartar. Cloth, dyed with a tartaro-sulphuric solution of tin thus made, and cochineal, took an aurora colour.

Tin dissolved by the pure acid of tartar, separated from its alkaline basis, (by the means usually employed for that purpose,) dyed with cochineal on cloth a very lively and beautiful scarlet, inclining a little to the orange. A similar colour was produced by water saturated with cream of tartar, in which granulated tin had been kept six weeks.

Tin may be readily dissolved by pure citric acid, and more slowly by lemon juice; and the solution newly made, dyes, with cochineal, a most beautiful scarlet, inclining, like the preceding, a little to the aurora. Indeed, I have repeatedly found, that the citric acid with tin, acts at least as efficaciously as that of tartar in yellowing the cochineal crimson. Nothing can exceed the beauty of scarlet dyed with the citrate of tin, and if it were not

too *costly*, this solution would deserve the preference of every other for dyeing scarlet.

Granulated tin, dissolved by strong vinegar, acquired a milky appearance, with a very particular, and somewhat of an unpleasant smell; and with cochineal it dyed cloth of a scarlet, inclining a little to the rose colour.

Tin dissolved by the pyroligneous acid produced with cochineal a colour between the scarlet and rose colour.

Phosphoric acid produced a permanently transparent and colourless solution of tin, which, with cochineal, dyed a bright yellowish scarlet.

Tin, dissolved by fluoric acid, produced with cochineal a very bright scarlet.

In addition to this account of experiments made previously to my first publication on this subject, I will mention a few of those which I have since made.

Tin having been dissolved by a *direct* mixture of pure nitric and muriatic acids, in equal proportions, the former of the specific gravity of 1500, and the latter of 1170, this solution, with cochineal and the common allowance of tartar, produced a very bright lively scarlet.

Tin, having been dissolved by a similar mixture, with an addition of sulphuric acid, equal to one fourth of the nitric, and the solution being afterwards employed with cochineal and tartar, as in the last-mentioned experiment, a salmon colour only was produced.

Tin, being dissolved in a mixture similar to that last mentioned, but with this difference, that *before* the sulphuric acid was added, tartar, amounting to three times the weight of the sulphuric acid, had been mixed with the nitric and muriatic; and this solution being employed with cochineal, and a little more tartar, a good scarlet was produced; the tartar which had been added *before* the sulphuric acid having, by its alkaline part, neutraliz-

ed the vitriolic acid, and obviated the evil produced by the latter, in the preceding experiment.

Having precipitated the oxide of tin, (by soda,) from the common dyers' spirit, or nitro-muriate thereof, and subjected this to the action of sulphuric acid, I found it incapable, with cochineal, of dyeing any colour more elevated than the *orange*.

After this account of the effects of the oxides of tin, in various states and combinations, when applied with cochineal on wool or woollen cloths, it is, I think, expedient for me to add a few other observations concerning those particular solutions of that metal, which are most frequently employed as mordants in dyeing, and the means by which they may be most advantageously obtained and employed.

It can hardly be necessary to premise, that for these solutions, the *purest* tin should always be selected, such as that of *Malacca;* next to which is that of Banca; and after it, the tin of Mexico is considered as most pure. In regard to the tin mines of Europe, those of Cornwall afford tin of the greatest purity; and after these, the tin of Bohemia is considered as preferable to that of Saxony.

The most frequent adulterations of tin are produced by intermixtures of arsenic, lead, copper, and iron. The first of these renders tin whiter and more brittle; the others give it shades of grey, which are dark, when either of the *two* last bears a considerable proportion. The means of detecting these adulterations have been mentioned by most of the systematic chemical writers. The presence of either iron or copper in tin, may be readily ascertained by dissolving a little of it in pure muriatic acid, and dropping the solution into a prussiate of lime, which will afford a precipitate more or less *blue*, if the

tin contains iron; and if it contains copper, a *reddish bronze* precipitate.

When pure colourless nitric and muriatic acids are mixed in quantities not very disproportionable, the former of these acids will be partially decomposed, with an exhalation of oxymuriatic acid, and a production of nitrous gas; but this last will remain for some time dissolved by the mixed acids, and give the mixture a red colour; and if granulated tin be added to the mixture, it will soon destroy this red colour, by expelling the nitrous gas; and will, moreover, cause a farther decomposition of the nitric acid, by combining with its oxygene; which combination renders it susceptible of a more speedy dissolution by the muriatic part of the compound.

Dyers, however, do not commonly produce their aqua-regia by a simple mixture of the nitric and muriatic acids, but by adding to single aqua-fortis a portion of sea-salt; and in so doing they, (without knowing it,) obviate the injury which the small proportion of sulphuric acid frequently contained, either in aqua-fortis or in muriatic acid, would produce, if allowed to act upon tin *in conjunction with nitric acid;* as I have found by numerous experiments. But in this way of producing a nitro-muriatic acid, the soda contained in the sea-salt, by combining with the sulphuric acid, and forming Glauber's salt, renders the latter incapable of any hurtful action; at least, if there be not more of it than the soda of the seas-alt can neutralize; and when this happens, the addition of a little saltpetre, which Hellot and others have thought beneficial, (without assigning any reason for thinking so,) would render this excess of sulphuric acid harmless, by affording potash to form with it a sulphate thereof.

By modern chemists, the solution of tin, when made by nitro-muriatic acid, is supposed to contain, or afford, only a *muriate* of that metal; it being assumed, that the

nitric acid suffers a *complete* decomposition, and that its oxygene is *all*, either expended to oxidate the metal, or exhaled with the nitrous gas. I believe, however, that the nitric acid is *never completely decomposed*, by this operation;* at least I have never found any solution of tin made by nitro-muriatic acid, which did not differ considerably in its *sensible* qualities, and also in its effects, as a mordant, with cochineal, &c. from a solution of that metal by pure muriatic acid. I attach no importance to the *straw, or amber*, colour of the solution of tin, commonly employed by the dyers, while the muriate of tin *is colourless;* because the colour of the former certainly results from the neutral salts which it holds dissolved; for, when the solution is made by a *direct* mixture of pure nitric and muriatic acids, it is as colourless as if it had been made by muriatic acid only; but in this case, it invariably exhales, and for a long time, the odour of nitrous gas, even when the acids were mixed in equal proportions; a certain proof, that the nitric acid was at most but partially decomposed.

* The proportion of either sea-salt or muriate of ammonia, employed by scarlet dyers in making their ordinary solution of tin, is by much too small to permit us to believe the result of that process to be merely a *muriate*. Hellot, who prefers a muriate of ammonia to sea-salt, prescribes as the *best* proportion, only half as much of it in weight, as of the metal employed; and Dambournay used a proportion smaller than Hellot's, which, however, is, I believe, that of most of the dyers, whether they employ sea-salt, or sal-ammoniac; and certainly, neither of these could afford muriatic acid sufficient to dissolve *twice its weight of tin*, as it must do, if the solution so produced were *merely a muriate* of that metal. I have sometimes employed a solution of tin, made by a diluted, but very pure nitric acid, with an addition of muriate of ammonia amounting *to no more than one-eighth* of the weight of metal so dissolved, which could have contained but a small proportion of muriate of tin; but this solution in a very few days will lose its transparency, and be capable of producing *only* orange salmon colours.

It has, moreover, several other peculiarities, particularly that of not affording *crystals* by evaporation, like the muriate of tin, and also that of becoming both opake and gelatinous by keeping, which does not happen to the muriatic solution; nor does it, when used in *excess*, injure the texture of wool, so much as an equal *excess* of the latter.

One cause of this *last* peculiarity, or difference, may depend upon the *production of ammonia*, whenever tin is dissolved by nitro-muriatic acid. Berthollet obtained satisfactory evidence of the reality of this production, even when the aqua-regia was made by a direct and gradual mixture of the pure nitric and muriatic acids; and he considers it as being a fact, which may enable us to understand, why in dyeing there is less difference than might be expected, between the effects of a solution of tin, made by this direct and simple mixture of the two acids, and those of a solution made by aqua-fortis with an addition of muriate of ammonia.

Besides this production of ammonia, M. Berthollet supposes, that *another* occurs in the dyeing operation, whenever the heat is near the boiling point; and that, by this, and the former production of ammonia, the acidity of the solution of tin is greatly diminished; which, as he thinks, will enable us to understand why the cloth is not injured by the common process for dyeing scarlet, though the *nitric* acid of *itself*, would, even when much diluted, produce hurtful effects upon it; and he also considers this as explaining the cause of the injury which the cloth suffered in my *first* experiment at the dye-house of Messrs. Goodwin and Platt.*

* After mentioning the neutralizing, or saturating effect of the ammonia, formed and acting, as has been just stated, M. Berthollet adds " on trouve encore dans cette action *saturante* l'explication

Having ascertained, as is mentioned in the note to p. 342, that a muriate of tin, containing only half the quantity of that metal, which the acid might have been made to dissolve, had operated as efficaciously as an equal quantity, containing twice as much tin, and in some respects with a better effect, in the dyeing of scarlet, I was led by this and other facts to suspect, that a much smaller proportion of tin than that which the dyers commonly dissolve in their nitro-muriatic acid, would produce equally beneficial effects. And, to ascertain the truth on this point, I put two drachms of powdered muriate of ammonia, into three ounces of strong nitric acid of the specific gravity of nearly 1500; and, having diluted this mixture by adding to it six ounces of water, I made it gradually dissolve fine granulated tin, until the acid was completely saturated; when I found that the tin so dissolved amounted in weight to a little more than half the weight of the nitric acid. On the same day I made another solution, similar in every respect to the first, excepting only that the tin dissolved therein weighed only half as much; and with these solutions, I made several experiments, the two following days, which were afterwards repeated, and in all of them I found, that the solution containing *only half* of the tin, which might have been dissolved therein, produced with cochineal, colours which *at least* were in every respect as good as those resulting from an equal quantity of the saturated solution; and after I had ascertained by several trials the smallest proportion of the half saturated solution of tin which was necessary to produce

d'une observation de *Bancroft*. Il vouloit substituer dans la teinture de l'ecarlate, le muriate d'étain, au nitro-muriate; mais, il en fallût une plus grande proportion, et la laine se trouvoit fort déteriorée. Dans cette operation, il ne pouvoit se former de l'ammoniaque, et l'acide muriatique, qui affaiblit facilement la laine, exerçoit sur elle toute son action." Elemens, &c. tom. i. p. 385.

a good scarlet upon a given weight of broadcloth, I found, that the *saturated* solution would only produce an *inferior* colour, when (on account of its greater proportion of tin) I diminished the quantity even but an eighth part. I conclude, therefore, that nearly one half the tin, which the scarlet dyers commonly dissolve with aqua-fortis, and a little sea-salt, to make what they denominate *spirit*, is *wastefully* employed; a fact which, considering the increased price of tin, may, by proper attention, produce a saving of very considerable importance. It appears to me, indeed, from a variety of considerations, that a proportion, and not a small one, of superfluous or *unsaturated* acid, is highly useful to enable the basis, or oxide of tin, actually employed, to produce its *utmost* and *best* effect, by conveying it more *copiously* and thoroughly, or with greater *penetration*, into the substance of the wool or cloth. For, with this superfluous acidity, I have repeatedly made the scarlet dye penetrate completely the *innermost* parts of the cloth, without any of the means mentioned in a note at p. 67, as having been employed by Mr. *Nash*, and his successor, for this purpose, and without any other means excepting the use of a superfluous acidity; and I think one of the benefits resulting from the employment of tartar, either with alum or with the solutions of tin, is that of furnishing a portion of uncombined acid, in *addition* to that which accompanies the aluminous or metallic basis; which basis, being thereby enabled to penetrate wool or cloth more intimately, afterwards attracts the colouring matter more copiously and thoroughly. It must however be observed, that this *superfluity* of acids may be too great; and that it should never be employed in the *same bath*, or liquor, which contains the cochineal, but always in the previous boiling; since all acids, when present in a large proportion, weaken or render *latent* the colour of that insect.

In regard to the *muriate of tin*, I may be allowed to premise, that the muriatic acid, in its liquid state, is necessarily combined with water; and that the proportion of the latter, in which the acid is best preserved, and most commonly sold, is such as to render its specific gravity equal to 1160, or at most 1170; and that, when of the latter degrees of strength, three pounds of it will dissolve nearly one pound of granulated tin, with the assistance of a sand-heat.

When *pure*, the muriatic acid is colourless; though it frequently exhibits a light straw colour, resulting, as is supposed, from a small portion of iron dissolved by it: but this disappears almost instantaneously, if a little tin be dropped into the acid.

The dissolution of tin by this acid, is always accompanied by a copious emission of *bubbles*, which, excepting a little of the acid escaping at the same time, appear to consist of *hydrogene*, disengaged, as has been generally believed, in consequence of a decomposition of the water previously united to the acid; which decomposition is supposed to afford oxygene sufficient to oxidate the metal, as far as is necessary to render it soluble by the muriatic acid. Davy, however, in reviving the doctrine of Scheele, endeavours to maintain, that the muriatic acid itself contains hydrogene, which, by this operation, is set free, while that, which he supposes to be its elementary part, and which he denominates *chlorine*, dissolves and combines with the metal. (See Phil. Trans. for 1810.)

Having already, in the introductory part of this volume, stated every thing which I mean to suggest, on *this* intricate subject, I shall proceed to observe, that however the emission of hydrogene may be explained, it is attended with a considerable escape of muriatic acid, which carries with it a portion of the metal itself, as is manifested by the smell. Gay Lussac considers himself

as having ascertained that tin, by being so dissolved, combines with 13,5 per cent. of oxygene; and that, by making a current of aqueous vapour pass over the metal, in a red heat, a white oxide may be produced, similar to that which is formed by subjecting tin to the action of concentrated nitric acid, and which, according to his experiments, consists of 27,2 parts of oxygene to 100 of tin. (See Ann. de Chimie, tom. 80, p. 169).

Those who wish to dissolve large quantities of tin by muriatic acid, will find it advantageous to decompose the dry sea-salt, by employing sulphuric acid in the proportion of five parts of the latter to eight of the former; using the precautions which have been prescribed, by chemical writers: and, by collecting the muriatic acid as set free in vapour, and conveying it immediately into large receivers, containing granulated tin with a little water, to absorb the dry acid vapour, the heat constantly and gradually evolved by that absorption, will, (as M. Chaptal asserts,) suffice to promote a solution of the metal, without any expense of fuel. (See Chimie, appliqué aux Arts. tom. iv. p. 182.) In this way, also, the loss of acid, and of tin, by evaporation, may be in a great degree obviated; as indeed it may be when common muriatic acid is employed for this purpose, if the solution by made in tubulated retorts.*

* Being at the house of Mr. Hawker, at Dudbridge, near Stroud, in Gloucestershire, during several of the last days of August, 1795, about twelve months after my first publication on this subject, that very estimable dyer informed me, that he had then lately begun to employ the muriate of tin for dyeing scarlet with good effect, and a considerable saving of expense in regard to the mordant; and he also showed me the way in which his muriate of tin was prepared, which was, by putting large portions of the granulated metal into muriatic acid contained in capacious, open vessels, and leaving it therein several weeks, assisted only by the summer's warmth: a great evaporation and waste of acid unavoidably occurred, and the

If muriate of tin, containing one-fourth of its weight of the metal, be sufficiently evaporated, it will afford considerably more than half its weight of solid transparent crystals, which are the heaviest of all the metallic salts; but the evaporation is accompanied with a pungent disagreeable odour, produced by an intimate combination of muriatic acid and tin, which is highly volatile; and, consequently, the bringing such a solution into a crystallized form, must be attended with a great loss, both of the acid and the metal.

Tin when first dissolved by muriatic acid, is supposed to be at the lowest degree of oxidation, but if the atmosphere be allowed free access to the solution, it will constantly absorb and unite with an increased portion of oxygene; and Pelletier pretends, that in proportion as it does this, and becomes *most oxidated*, it also becomes most efficacious and useful as a mordant in dyeing.* But his experiments certainly do not warrant any such *general* inference; and the numerous trials which I have made of this metal as a *basis*, (with cochineal, quercitron bark, &c.,) at various, and probably at all the possible degrees of oxidation,† have abundantly convinced me, that the

acid, as far as I could judge, was not more than half saturated; which doubtless was an advantage.

* See Mem. et Observat. de Chimie, tom. i.

† I am aware that modern chemists are disposed to consider tin as only susceptible of two stages or degrees of oxygenation; the lowest called a *protoxide*, in which the metal contains about 13 per cent. of oxygene; and the highest called *peroxide*, in which, according to some estimations, it is at about 24 oxygene to 76 of tin, and, according to others, at 28 to 72. I believe, however, that in my experiments, I have employed this metal at several intermediate stages or degrees of oxidation, notwithstanding all that has been written, and particularly by Professor Berzelius, on the *determinate proportions* in which the inorganic elements of nature are supposed to unite.

oxide of tin acts most powerfully in exalting and giving vivacity to colours, when it is *but little* oxidated, and that every degree of oxygenation beyond a certain unascertained number, tends to reduce or diminish the *high* red of the cochineal dye, and at the same time to make it incline to, or partake of, too much of the *orange*, so as only to produce, when highly oxidated, what I have denominated a salmon colour. Such is invariably, and in a remarkable degree, the effect of tin, when it has been subjected to the action of sulphuric acid alone, or in conjunction with the nitric; and also after it has been for some time rapidly dissolved by pure nitric acid but little diluted; and it can hardly be necessary for me to add, that in all these cases the metal will have obtained a higher degree of oxygenation. Similar effects, though in smaller degrees, have been found to result from a variety of combinations by which the oxide of tin, though less oxygenated than in the former, was yet too much so to produce its best effects.

In stating as my opinion, that tin is most efficacious in raising and giving brightness to colours, when *but little* oxidated, I purposely avoided the word *least*, because my experiments do not warrant me to say that colours are not as much exalted, and enlivened, by a muriate of tin, to which a little nitric, or a little sulphuric acid has been added, (after the solution was made,) as by the muriate alone, when recently made; provided that only one of these acids be added; for both together would, as has already been observed, render the tin incapable of producing, with cochineal, any thing more elevated than a salmon or orange colour. But in attributing such effects to variations in the degrees of oxidation, at which tin is employed, I desire not to be understood as believing, that these *alone operate*, in producing differences in the shades of cochineal colours, or that the several acids employed

do not exercise a very considerable influence, in this respect, by their peculiar properties, independently of their effects in oxygenating the metal itself.

In concluding these observations concerning the muriate of tin, I beg leave to repeat, what has been already mentioned, that though it certainly acts more strongly than any other solution of that metal, in weakening the fibres of wool, especially when the acid is saturated by the metal, it may, when the latter is dissolved more sparingly, be employed with perfect safety, (and a considerable saving of expense,) and more especially in conjunction with the usual proportion of cream of tartar; and even with a considerable proportion of sulphuric acid, which indisputably, though perhaps unaccountably, moderates this hurtful action of the muriate of tin,* as indeed *every other acid* seems to do.

I have mentioned with approbation, between pages 286

* A manufacturer who supplies the country dyers with not only the muriate, but the murio-sulphate of tin, (recommended at p. 358,) assures me, that to produce the *latter* he first prepares the muriate of tin, which he sells of two sorts; in one of which the dissolved metal amounts to a fourth, and in the other to a fifth part of the solution; and by gradually adding to either of these two-thirds of its weight of concentrated oil of vitriol, he produces a murio-sulphate of tin, in which, however, the acids are not more than half saturated; but, notwithstanding the great strength of these acids, the solution has not been even suspected of producing any injury to cloth dyed with it; and the preparer of it asserts, that it produces the best effects after being kept several years. No length of time which has elapsed since it was first made and recommended by me, seems capable of diminishing its *colourless transparency*, which equals that of the clearest spring-water; a circumstance which seems not a little extraordinary, when we consider that sulphuric acid *alone* is speedily decomposed by tin; sulphur being *distinctly* produced, and the tin itself converted to a brownish calx, which subsides in a *mass* to the bottom of the vessel, in which the decomposition has been effected.

and 291, the results of several experiments made, by MM. Thenard and Roard, to ascertain the effects produced on wool, by b·iling it with the usual proportions of alum and tartar, and also with the usual proportions of the latter, and of the nitro-muriate of tin, as employed for the dyeing of *scarlet;* and it seems proper that I should here notice some other parts of their "*memoire*," which relate more immediately to the production of this colour.

"Scarlet, (they say,) is obtained by treating wool with determined proportions of cochineal, acidulated tartrite of potash, and a *highly oxydized solution of tin.*" "The operation is divided into two parts; the first taking up an hour and a half, and the second half an hour:" "This division (they add) is necessary to produce a good colour, which would be weaker and more yellow if all the substances were mixed in the first operation and applied to the wool for two hours," by reason of the acidity of the bath or dyeing liquor. "We obtain," say they, "a contrary effect when the mordants *only* are employed in the first operation, and the cochineal is reserved for the second." They, however, contradict this *last* position, in another part of the same memoir, by asserting that wool, combined with the mordants in question, and dyed afterwards separately with *cochineal only*, *will never become scarlet;* because this colour, as they allege, can only be produced by a cochineal bath, which is very acid "tres acide," "et qui en faisant *passer au jaune*, le ton de la cochenille, donne alors tant d'eclat à cette couleur."* But the effect of tartar, which principally causes this approach to yellow, in the cochineal colour, may, as I have found by scores of experiments, be very well produced, together with that of the solution of tin, by the

* See Ann. de Chimie, tom. lxxiv. p. 290.

first boiling; and a very fine scarlet be afterwards dyed by the *second* with cochineal alone, taking care only, when no tartar or tin is intended to be employed in the last operation with the cochineal, that a full proportion of them be employed in the first, and that their effects be not removed or diminished by *rincing the cloth*, between the first and second boilings. In regard to the inconvenience of dyeing scarlet by a *single* operation or *boiling*, I will only observe, in addition to what I have stated on that subject at p. 337, that where *only a bare sufficiency* of cochineal is employed, with a *full* proportion of the mordants, and especially of tartar, the colour, though very lively, will appear rather deficient in quantity, or body, because the cloth will not completely *exhaust* the dyeing liquor of its colour, when the acids are in excess. This, however, will not ultimately be attended with any waste of colour, because dyers, by a *succession* of undyed pieces, know how to take up, and fully avail themselves of every thing left, by a former operation.

In regard to the high degree of oxidation of tin, which these gentlemen consider as necessary for producing a scarlet, I must conclude, that they have been misled by the opinion of Pelletier on this subject, or that they have supposed the solutions employed by them to be much more oxygenated than they really were. Certainly I have produced, as I believe, more than one hundred times, scarlets as beautiful as can be any where found, by the *recent*, and little, perhaps least, oxidated muriate of tin, with only the usual proportions of tartar and cochineal; and I have very often found myself unable to produce any thing better than an orange or a salmon colour, by solutions of tin, which certainly were *highly oxygenated.* Indeed, the dyers notoriously and universally consider their spirit, or nitro-muriatic solution of tin, as being unfit for their purpose, when it loses its transparency; an effect

which indicates, and results from a greater degree of oxygenation in the metal.*

In another part of their memoir, these gentlemen are pleased to say, that though the process for dyeing scarlet has long been known, no person has made any theoretical researches, concerning the phenomena which occur, when the solution of tin, cream of tartar, and cochineal, are made to act upon, or with each other, " dans le traitement de la dissolution d'étain avec la crême de tartre et la cochenille;" adding, that I, who (as they observe) have occupied myself with great success in dyeing, have indeed endeavoured to explain what occurs in the formation of the scarlet colour; but that as my opinion does *not seem to them to have been founded upon any experiment*, they are intitled, notwithstanding that opinion, to consider the question as being no more decided, than it was before the publication of my work.† As these gentlemen distinctly assert, in this their memoir, that the production of a *scar-*

* I have said, at p. 376, that the straw or amber colour of the solution of tin, commonly employed by dyers, appeared to result from the neutral salts which it holds in solution. I have, however, since discovered that I was then misled by an experiment which ought to have been differently explained, and that *this* colour may be instantly either produced, or increased, by adding a very little muriate of tin to the nitro-muriate of that metal; the former, by being thus added, producing a decomposition of the nitric acid in the latter, and a disengagement of *reddish nitrous gas*, which occasions the colour, and affords an additional proof of my assertion, at p. 376, that the nitric acid is never completely decomposed, in the dyers' spirit, or nitro-muriate of tin.

† " Le Docteur Bancroft, qui s'est occupé avec beaucoup de succés, de la teinture, à bien cherché indiquer ce qui se passe dans la formation de cette couleur, mais comme son opinion ne nous paroit appuyée sur aucune expérience, nous n'en devions pas moins regarder cette question comme aussi peu avancée qu'elle l'étoit avant la publication de son travail." Ann. de Chimie, tom. 75. p. 288.

let colour (instead of a rose or crimson) by the common process, is due to the action of the acid of tartar, and as this is precisely what I had distinctly asserted and maintained *sixteen years before*, I must understand them not as intending to controvert my opinion, but to represent it as one which, though correct, had been formed or *hazarded*, without any experiment or evidence; and that, therefore, what I had done, was of little or no value, and that they were alone entitled to the credit of having ascertained and established an important fact.

Not finding in myself any desire to conceal, overlook, or undervalue the labours of others, to render my own more important, I am unwilling to suspect that desire in these gentlemen; but I can only avoid doing so, by supposing that when they ventured to represent me as having made no experiment on this subject, they were not only ignorant of, but culpably negligent in ascertaining the truth, as they might have done by recurring to the statements between pages 284 and 288 of the volume published in 1794, (now reprinted between pages 352 and 355 of this volume,) which abundantly manifest that the opinion in question, was not only supported, but had been forced upon me, by a great number of decisive experiments.

Broadcloths, as commonly manufactured, vary in width from 60, to 63 inches; and they vary also considerably in substance or weight. Of three samples of scarlet broadcloth which I weighed, the heaviest, said to be Mr. Nash's, was equal to one pound eight and one half ounces per yard, and the lightest to one pound two ounces and one-tenth. Cloths when dyed of the greater part of the colours in use, shrink and acquire weight; but when dyed scarlet, they, by reason of the action of the acids employed, become of *less weight*, and each piece is made a yard or two longer; the effect of *fulling* being in some degree

undone; and when so lengthened, they are said to be *leached.*

Having thus communicated the results of my observations on the uses of tin, in various combinations, as a mordant upon wool with the cochineal colouring matter, it remains for me to state, as shortly as possible, the effects of other bases with the same colouring matter also upon wool or woollen cloth.

Cochineal with nitro-muriate of platina, dyed a red; which, by the addition of carbonate of lime, became a chesnut colour.

With nitro-muriate of gold, it dyed a reddish brown.

With nitrate of silver, a dull red; and with muriate of silver, a lively reddish orange.

With the acetite of lead, a purple, inclining to the violet; and with nitrate of lead, a delicate lively colour, between the red and cinnamon, but inclining most to the former. A little murio-sulphate of tin, added to the liquor in which this last was dyed, soon changed it to a good crimson.

With either the sulphate, nitrate, muriate, or acetate of iron, cochineal produces a dark violet, and even a full black colour, when employed in sufficient quantity.

All the preparations of copper appear to sadden and debase the colouring matter of cochineal; and all those of mercury, which I have tried, do this in much greater degrees; most of them, whilst they debase the colour, seem to annihilate or render *latent* a considerable part of it.

With nitrate of zinc, cochineal dyed a lively strong lilac colour approaching nearly to purple; and,

With muriate of zinc, a colour like the preceding, but inclining a little more to the purple. Probably the iron usually contained in zinc may have contributed in these instances to incline the cochineal crimson so much to the

blue or violet shades, since an oxide of zinc, in some very pure lapis caliminaris, being dissolved by muriatic acid, dyed (with cochineal) a scarlet, but little inferior to that commonly produced with the nitro-muriate of tin and tartar, except in being a little more yellow; and upon adding a little murio-tartrite of tin to the dyeing liquor, it soon produced a good scarlet. The pure oxide of zinc, therefore, seems to approach nearest to that of tin, in exalting the colouring matter of cochineal; though I believe the colours resulting from it are less durable than those with the basis of tin.

With different solutions of bismuth, cochineal produced various shades of lilac; some of them very lively and delicate; but all preparations of this semi-metal, instead of displaying and exalting the cochineal colour, tended to render a part of it latent. The oxide of bismuth, dissolved in strong vinegar, did this less than most of the other preparations; it dyed with cochineal a pretty good purple, and the murio-sulphate of bismuth, a salmon colour.

With nitrate of cobalt, cochineal dyed a good purple, and a violet with the sulphate of that metal.

With nitrate of nickel, a dark lilac, inclining to the violet.

With yellow oxide of tungsten, cochineal dyed a red much like that commonly obtained from madder.

With sulphate of manganese, an orange; and,

With the nitrate of manganese, a colour resembling the madder red.

With crude antimony, which had been subjected to the action of nitric acid, cochineal dyed a scarlet very much like that dyed with lapis caliminaris dissolved by muriatic acid, and but little inferior to the best scarlets given with the tin basis; and,

With Macquer's arsenical neutral salt, or the acidu-

lous arseniate of potash, cochineal dyed a lively good purple; and with common white arsenic a full dark lilac colour.

Such were the effects of different metallic bases, in dyeing with cochineal on woollen cloth. Of the simple earths I have only tried alumine and silex as bases with cochineal. Those of Zircon, Glucine, (or Glycine,) and Yttria (or according to Dr. Young, Ittria,) being too *rare* and *costly* for this use.

The effects of sulphate of alumine, or common alum, with cochineal, and especially in dyeing crimson, are well known. Alumina, or earth of alum, (obtained by decomposing and precipitating it by potash from water, saturated with alum,) when thoroughly washed, dried, and finely powdered, did not seem capable, in repeated trials, of *alone* fixing or serving as a basis of the cochineal colour on wool. In this respect it differed from the powdered calx of tin.

But the powdered alumine, being boiled up with cream of tartar, was so far dissolved by its acid, that with cochineal it dyed a good crimson, though not much better than that which may be produced with the sulphate of alumine.

The same powdered earth of alum, dissolved by lemon juice, dyed with cochineal a very good rich full crimson.

The same powdered earth of alum dissolved by nitric acid, (and forming nitrate of alumine,) produced a good red, inclining to the crimson.

The same dissolved in muriatic acid, (muriate of alumine,) dyed a crimson, differing but little from that produced with common alum.

The silicated alkali of Dr. Black, or powdered flints, dissolved by a violent heat in a crucible, with pure caustic alkali or potash, was tried as a basis for the cochineal colour. At first, the fibres of the cloth did not seem to

have sufficient attraction for the siliceous basis and the colouring matter, to attach and fix them properly; but on adding a little sulphuric acid, so as to decompose and neutralize a part of the alkali, which had dissolved and was combined with the siliceous earth, the colour took freely, and rose to a *full*, *rich*, *pleasing purple*, in which the red or crimson predominated considerably; and this colour afterwards proved sufficiently durable.

In regard to *alkaline* earths, (so called,) I found that lime-water with cochineal dyed a purple, which took but slowly, and required long boiling.

That sulphate of lime, or lime dissolved by sulphuric acid, dyed a full dark red.

That nitrate of lime, or lime dissolved by nitric acid, dyed a lively red, approaching to scarlet.

And that muriate of lime with cochineal dyed a purple.

Cloth boiled in water with *nitrate of lime*, and then dyed in clean water with cochineal and tin, dissolved by aqua-fortis and tartar mixed, received a good scarlet.

Cloth boiled with carbonate of lime and alum, and then dyed in clean water with cochineal, took a good crimson, inclining to the bluish shade.

Sulphate of barytes, or ponderous spar, not being soluble in water, was not tried.

But muriate of barytes, employed as a basis for the cochineal colour, dyed a good lively purple; and

Nitrate of barytes dyed a colour nearly similar, but inclining a little more to the crimson.

Magnesia alone did not combine sufficiently with the fibres of cloth, and with the colouring matter of cochineal, to serve as a basis for dyeing.

But magnesia dissolved by sulphuric acid, (forming Epsom salt,) dyed a lively purple with cochineal, though

it took but slowly, and required long boiling. The acetate of magnesia dyed a lilac colour.

Strontites, or strontia earth, dissolved by muriatic acid, and employed as a mordant with cochineal, produced on woollen cloth an orange colour.

It appears, therefore, that besides the metallic oxides and solutions, the *simple* earths, so far as they have been tried, and *all* the *alkaline*, are capable of serving as bases of the cochineal colouring matter, though not with equal advantage; and we shall hereafter find, that they are capable of doing the same to other adjective colours; a fact never before ascertained, though of great importance, as well in respect of the practical improvements which it may produce, as of the general principles and conclusions to which it may lead us on this subject.*

I have repeated nearly all the foregoing experiments with silk, instead of wool, and generally with effects less advantageous. Cochineal, indeed, with the aluminous basis, dyes the crimson colour as well and as durably on silk as on wool, and the modes of producing a very lasting crimson by these means are well known. But the oxides or solutions of tin tend to diminish the shining glossy appearance of silk, and therefore, when applied to it, do not reflect the cochineal colour with the same degree of fulness and lustre as upon wool; and it has, therefore, been found impossible to dye a good lively scarlet on silk by the means which communicate that colour to wool.

* I have found that cochineal has so much affinity for wool, that if the latter be boiled with a portion of sulphuric acid sufficiently diluted, and afterwards dyed with cochineal, it will, without any other basis, take a *red* colour, capable of bearing exposure to the sun and air for some weeks, though fewer than if dyed upon a suitable basis. But cotton will take no colour in this way.

The late Mons. Macquer, indeed, about the year 1768, pretended to have discovered the means of dyeing a scarlet upon silk by a process which he published in the Memoirs of the Royal Academy of Sciences for that year. According to that process, he began by dyeing the silk first of a yellowish orange colour, with annotta applied in the usual way; then he soaked it for half an hour in a diluted solution of tin, made by a mixture of two parts of the nitric with one of the muriatic acid; after which the silk was taken out, moderately pressed, and rinced in clean water, though he afterwards found it better to omit the rincing. To dye the silk, when thus impregnated with nitro-muriate of tin, he prepared a bath, by boiling from two to four ounces of cochineal and a quarter of an ounce of cream of tartar, for each pound of silk, some minutes in water; after which he added cold water, until the heat of the liquor was reduced to what the hand could bear, and then put in the silk, and dyed it as usual, gradually raising the heat of the dyeing liquor, so as at last to make it boil for a single minute. I have several times repeated this process, but always found the colour produced by it very inferior to the scarlets usually dyed on woollen cloth; and M. Berthollet informs us, that this was also the case at the trials which M. Macquer himself made of his process at the dye-house of the Gobelines; and in truth there was nothing of any importance in Macquer's supposed discovery. It seems, indeed, to have been chiefly borrowed from a process published by Scheffer, in 1751, excepting so far as relates to the colour first given with annotta, and excepting a difference in the proportion of muriatic acid for dissolving the tin; a difference, however, which did not render the solution in any respect more efficacious.

If the murio-sulphuric solution of tin, herein before described, be diluted with about five times its weight of

water, and silk be soaked in it for the space of two hours, then taken out, moderately squeezed or pressed, afterwards partly dried, and then dyed, as usual, in a bath prepared with cochineal and quercitron bark, in the proportion of four parts of the former to three of the latter, it will receive a colour approaching very nearly to a scarlet; and this may be made to receive more body by a farther slight immersion into the diluted murio-sulphate of tin, and a second dyeing in the bath with cochineal and quercitron bark; and if afterwards a little of the red colouring matter of safflower be superadded by the usual mode of applying it, a good scarlet may be produced. By omitting the quercitron bark, and dyeing the silk (prepared as before mentioned) with cochineal only, a very lively rose colour will be produced; and this may be yellowed so as nearly to approach the scarlet, by adding a large proportion of tartar to the cochineal in the dyeing vessel.

With lime-water as a mordant, cochineal gave to silk a very agreeable purple; with muriate of barytes, a lively delicate lilac colour; with murio-sulphate of bismuth, a salmon colour; and with nitrate of cobalt, a very lively and beautiful purple; with nearly all the other metallic and earthy bases cochineal produced similar, but paler colours on silk than on wool.

The scarlet dye is still less applicable to *cotton* than to silk, there being, unfortunately, but a slight affinity between the former and the oxide of tin, even when united with the colouring matter of cochineal. This was demonstrated by the late M. Dufay, who caused a piece of cloth to be manufactured from a mixture of wool and of cotton, which having undergone the usual process for dyeing scarlet, became, as he describes it, "marbrée de couleur de feu et de blanc," (marbled with white and fire colours,) the cotton remaining perfectly white, though the wool was dyed scarlet: and he found a like want of

attraction between cotton and the colouring matters of kermes and stick lac. He morever found that a skein of white woollen yarn, and another of cotton, being at the same time, and in an equal degree, submitted to the action of the same preparation, and dyeing liquors, which are commonly employed for scarlet, the woollen yarn received a beautiful scarlet, or, as he terms it, "*fire colour*," whilst the cotton remained as white as at first.* Similar effects† have frequently occurred to me, and I have clearly perceived them to arise, not because the cotton is not capable of imbibing the scarlet dye; but because, having a weaker attraction for it than that which wool exerts on the particles of that dye, the latter *draws, and exclusively appropriates to itself*, all the colour contained in the dyeing liquor; though when cotton is subjected to the same process by itself, freed from the interference of a superior attraction from wool, it takes a scarlet colour, as I know by repeated trials, more slowly, indeed, and paler, than that which is usually imbibed by woollen cloth. It is, perhaps, owing to this weaker attraction between the fibres of cotton, and the scarlet dye, that the latter is so much less permanent on cotton than on wool; and it is also from this want of sufficient attraction, that the cochineal colour is found to take most benefi-

* See Mem. de l'Acad. Ro. des Sciences, &c. 1737.

† In the dyeing of scarlet, it is every day seen, that pieces of woollen cloth or stuff, having at each edge a narrow longitudinal stripe, formed by an intermixture of cotton yarn, after being impregnated in the usual way with the mordant or oxide of tin, will attract and imbibe the colouring particles of cochineal, so as to exhaust the dyeing liquor, and sometimes leave it perfectly colourless, and become scarlet in every part, excepting the stripes formed of cotton-yarn, which always come out of the dyeing liquor without the smallest tinge or change of colour, though both the mordant and the particles of cochineal are applied to the latter equally with the other parts of the cloth.

cially on cotton, when the basis has been *first applied separately.*

Scheffer, in 1751, recommended the dyeing of scarlet on cotton in this way, by first soaking it in a diluted nitro-muriate of tin, and afterwards dyeing it with cochineal; but the colour being fugitive, little or no use was ever made of the process; though the late Dr. Berkenhout probably availed himself of it some years afterwards, when he pretended to have discovered the means of dyeing "scarlet, crimson, and other colours, upon cotton and linen;" and though his process was not materially different from that of Scheffer, nor in any respect preferable to it, he found means to obtain 5000*l.* sterling from the British government, as a reward for making it public.*

* Dr. Berkenhout's process having, I believe, never been published, I shall subjoin the account of it, which was "communicated by order of the Lords of the Treasury to the Company of Dyers in the City of London, the 26th of August, 1779;" viz.

"Cotton or linen, either in yarn or the piece, should be perfectly wet with hot water, and then wrung out, as is the common practice.

"This being done, it must be perfectly soaked in a solution of tin, diluted with an equal quantity of clear soft water.

"The cotton or linen being so far prepared, must be wrung out, but not forcibly; then it is to be nearly dried, laying horizontally upon a hurdle, with a double linen sheet between and covered with the same.

"The solution of tin being for scarlet, must be made of nitrous acid, and not of aqua-fortis; but for crimson, aqua-fortis must be used; and the bloom is to be given, after it comes out of the dye, by a small quantity of sal-ammoniac and pearl ashes, dissolved perfectly in warm water; but this water must not be more than milk-warm.

"The colouring vat, for the scarlet or crimson, is simply cochineal in water, no hotter than the hand will bear; and as vegetable matter receives only the small particles of the colour from the nature of its pores, two ounces to a pound of the materials dyed may be necessary; but cotton or linen, fresh prepared, will draw from

But as no use ever has been, or is likely to be made of this supposed discovery, I must hope, and, indeed, I think it probable, that the Doctor had some better claim to a national remuneration, though, from particular considerations, it was not brought into public view.

Besides the fugitive nature of the scarlet dyed by Dr. Berkenhout's process, which, indeed, is calculated to produce only a crimson, and not a scarlet, unless some yellow colour be superadded by other means (which he does not mention,) it is liable to injure the texture of the cotton or linen dyed with it, because the nitric calx of tin, applied as the basis, constantly absorbs oxygene from the atmosphere, and becomes corrosive, whereas, in the present

the same vat, heated as before, all the inferior shades from scarlet and crimson: and if any colour still remains in the vat, it may be taken out entirely by wool prepared in the usual manner.

"The same preparation of tin serves for the greens and yellows, with the same materials only that are employed by dyers, except the best yellow, which is produced from turmeric.*

"It is necessary to observe, that after the preparation has been made use of for scarlet or crimson, the residue continues sufficiently strong for greens or yellows, even after it has been kept a considerable time.

"N. B. To make the best solution of tin with nitrous acid, it is necessary to have the strong smoking spirit, to which an equal quantity of the purest river water must be added, and the proportions of the following ingredients, are to the weight of spirit, one-sixteenth of sal-ammoniac and one-thirty-second of refined nitre dissolved by little at a time; in this aqua-regia dissolve one-eighth of granulated tin, also by small quantities, to prevent too great an ebullition, which would weaken the solution considerably. The ingredients and proportions are the same, when a solution is to be made with aqua-fortis; but that spirit, in general, will not bear any water when a perfect solution is intended."

* Nothing can be more erroneous than this and several of Dr. Berkenhout's other observations.

case, this effect cannot be counteracted by occasional washings with soap.

Mr. Henry says, that "if a scarlet could be dyed without the use of nitrous acid, the tin basis might be employed for this purpose on cotton; but *that acid being requisite for the production of this beautiful colour*, and being highly corrosive to colours, this basis is prevented from being applied to that substance."—Here this ingenious chemist appears to have fallen into the universal error of believing, that nothing but a solution of tin by nitric, or nitrous acid, can dye a scarlet colour with cochineal.

If, notwithstanding the want of sufficient permanency in the scarlet colour dyed with cochineal upon cotton, it should be deemed proper to apply it to that substance, the best way of doing this which I have yet found, is, to soak the cotton, (previously moistened,) for about half an hour in a diluted murio-sulphuric solution of tin, as proposed for silk; then wring or press out the superfluous part of the solution of tin, and plunge the cotton into water, in which as much, or nearly as much, clean potash or soda has been dissolved as will neutralize the acid still adhering to the cotton, so as thereby to decompose the oxide of tin, and cause it to be more copiously deposed or fixed in or upon the fibres of the cotton, which, being afterwards rinced in clean water, may be dyed with cochineal and quercitron bark, in the proportions of about four pounds of the former to two and a half or three pounds of the latter. A full bright colour may be given to cotton in this way, which will bear a few slight washings with soap, and a considerable degree of exposure to air. Indeed, the yellow part of the colour obtained from quercitron bark will even bear long boiling with soap, as well as the application of strong acids, without injury.

Cotton impregnated or printed with the aluminous

mordant, as commonly applied by calico-printers for madder reds, will, if dyed with cochineal, receive a very beautiful crimson colour, capable of bearing several washings, and of resisting the weather for some time, though not long enough to deserve the appellation of a fast colour. I think, however, that it is advantageous for calico-printers, in dyeing madder reds upon the finer cottons or muslins, to add also a little cochineal, the crimson colour of which is admirably calculated to overcome the yellowish hue that degrades the madder reds, and arises from a portion of that particular colouring matter which produces the *fauve*, or fawn colour, herein before mentioned. By this addition, the madder reds are rendered much more beautiful, so long as any part of the cochineal crimson remains, and afterwards they are no worse than if it had never been applied.

Cotton printed with iron liquor takes a very full black when dyed with cochineal; but I found this less durable than the same colour dyed from much cheaper matters. A great variety of other colours may be dyed upon cotton impregnated with different metallic or earthy bases; but as better colours may be more cheaply given by other means, I shall offer no farther explanations respecting them.

A strong decoction of cochineal, thickened with gum, and mixed with a suitable proportion of nitrate of alumine, being penciled upon cotton as a pro-substantive colour, afforded a very full beautiful colour between the scarlet and crimson, which stood some washings, and a considerable degree of exposure to weather. Several of the different solutions of tin being employed, instead of the nitrate of alumine, as well as conjointly with it, produced very beautiful rose colours, approaching more or less to the scarlet; and by adding a small proportion of the quercitron bark, they were made scarlet. They could not, in-

deed, be considered as fast colours, but had the advantage of being very beautiful, and less fugitive than many of those which are too frequently employed by calico-printers, under the denomination of chemical colours.

Since the preparation or manufacture of Morocco leather has been established in this country, *cochineal* is employed to communicate the beautiful colour of *that*, which is called *red* Morocco; though in Persia, Armenia, Barbary, and the Greek Islands, a similar colour was originally produced by the use of either *kermes* or *lac*. As a basis for the colouring matter of cochineal, goat-skins deprived of their hair by lime water, and properly cleansed, are impregnated, on that which was the *hairy side*, with a saturated solution of alum, applied repeatedly and equally by a sponge, and after an interval of three or four days, a decoction of cochineal, which has been strained, is applied also by a sponge, to the same side or surface, a little, but not much, more than blood-warm, least it should crisp the leather. This application is repeated from time to time, until a colour sufficiently full and equal has been produced. Afterwards the skins are soaked in bran liquor, and then tanned by a decoction of either galls or sumach, or of both mixed together.

I have found that by substituting a diluted murio-sulphate of tin, for the solution of alum, or by employing a mixture of both upon goat-skins in a suitable state of preparation, the colour subsequently produced was considerably improved, at least in vivacity.

Having nothing more of importance to communicate respecting cochineal, I shall here finish this chapter, and in so doing, make an

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